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THE TECHNIQUE OF THE SYME AMPUTATION *

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The merits of the Syme amputation, first described over a hundred years ago, have been debated more than those of any other major amputation. This operation, although well known, was not employed very widely in this country prior to World War II. Little use of it was made in World War I on American wounded, and there were very few good results. Although some American surgeons have recognized its value and have advocated it consistently, most of them have not made full use of it for various reasons, the most important of which has been fear of unsatisfactory end results.

The Syme amputation was employed rather extensively by the British and Canadians in World War I. The follow-up on the British cases at the Amputation Center of the Ministry of Pensions at Roehampton, England, has shown the results to be so unfavorable that the surgeons and limb-fitting surgeons there have condemned the operation completely. They have stated that the chief cause of failure was imperfect stumps, which resulted from surgery done in the presence of, or too soon after, sepsis.

Among the Canadians, on the other hand, many good Syme amputations were done in World War I; and many Canadian surgeons strongly advocate the operation, whenever it is indicated.

At the beginning of World War II, the authors had had very little experience with the Syme amputation, but soon began performing it on carefully selected patients, wounded in the War. The immediate results were so encouraging that the operation was soon performed without hesitation in any case in which it was definitely indicated. Seventy-five Syme amputations have now been performed by the authors during the past three years in the Army. The fundamentals of the technique described here have been followed on all cases from the beginning; but minor changes and improvements have been made from time to time, until the operative technique now used has been developed. Because the proper selection of cases and the after-care are just as important as the operative technique and have such important bearing on the results, these phases are also discussed.

The purpose of this paper is to present the methods employed and the technique found to be useful in obtaining satisfactory results in a very high percentage of Syme amputations.

ADVANTAGES

The Syme amputation has definite advantages over amputations below the knee and over most short foot amputations, which often produce poor functional results. The Syme

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method is far more conservative and the limb is better functionally than with an amputation below the knee. Patients having good Syme amputations are truly appreciative of the conservatism elected for them, and no case is known in which the patient would prefer to have had any other type of amputation. The Syme operation offers the best major amputation of the lower extremity in that the longer stump gives better leverage; and it is capable of full end-bearing, with or without a prosthesis. This factor is definitely of value in walking about the house. Psychologically, the Syme amputation is preferable to amputation below the knee, because the patient considers himself merely inconvenienced and not really handicapped. In bilateral amputation of the lower limb, a double Syme amputation is far preferable to a double below-the-knee amputation, because the patient can walk with a better gait and can stand longer. The Syme prosthesis does not extend above the knee; hence there is no necessity for a pelvic belt for suspension of the limb. If a double Syme amputation is impossible, one is always highly desirable in combination with an amputation below or above the knee, because the patient can protect the stump which is not end-bearing from too much use by relying primarily on the extremity with the Syme amputation for locomotion and prolonged standing. The authors have had personal experience with eight patients, each of whom had a Syme amputation on one side and a below-the-knee amputation on the other side; all prefer the Syme amputation to the below-the-knee type. Some of these patients have worn their prostheses for over a year. Patients in a large Amputation Center, where good results from the Syme operations are plentiful, prefer the Syme amputation to the below-the-knee type, as well as to most short amputations of the foot. Contrary to the generally accepted view, the Syme stump is simpler to fit with a prosthesis than a below-the-knee stump, and the prosthesis does not require as many adjustments after it has been fitted. The reason for this is that the Syme stump is fully end-bearing, and the socket does not have to be fitted as accurately to transmit the body weight through the soft skin of the leg as in the average below-the-knee prosthesis.

The Syme amputation also has many advantages over amputations through the foot which are too short for good function. When the metatarsals have been lost, the body weight has to be borne by the heel and what is left of the fore part of the foot. Frequently there is muscle imbalance, which results in the strong and improperly opposed group of calf muscles pulling the foot into fixed equinus. This lifts the heel and lowers the end of the foot stump so that the heel no longer takes its share of the weight, while the end of the foot stump (which is often scarred) is forced to take more than its share of weight. This results in weight-bearing on one small point on the end of the stump, which becomes calloused and later breaks down. If the end of the stump happens to be scarred, it breaks down without callus formation.

In the Syme amputation the normal tough plantar skin of the heel is brought forward directly beneath the end of the tibia, where the weight of the entire body is transmitted into the socket of the prosthesis, without any friction against scarred areas. The Syme prosthesis is simpler to fit than any prosthesis which has yet been developed for the Chopart type of amputation. Patients who have had a Syme amputation have a better gait and far less pain and discomfort than patients with poorly functioning short foot stumps. The stump resulting from the Syme amputation is preferable to any short foot stump, which cannot be made, by surgery and proper fitting, to provide good function from the standpoint of locomotion and weight-bearing. The Syme amputation is the only amputation recommended at the ankle joint, and is preferable to any of its modifications, including the Pirogoff amputation.

DISADVANTAGES

It is unfortunate that, where amputations of the lower extremity are necessary, the Syme amputation cannot be used oftener. Approximately 2 per cent. of American Army

amputees from World War II have had the Syme amputation. This percentage seems low, but it is greater than that for several other sites of amputation,—such as the hip, knee, wrist, elbow, and shoulder joints. The low percentage of Syme amputations should in no way minimize the value and importance of the operation, as the number will increase with more widespread recognition of its merits.

The Syme amputation requires greater skill on the part of the surgeon in the proper selection of cases, the operative technique, and the postoperative care than any other amputation. The results, however, improve with the experience of the surgeon. Generally speaking, the Syme amputation requires a longer period from operation to limb-fitting than the below-the-knee amputation, but frequently the stump is ready for final fitting just as early as a below-the-knee stump. The bulbous ankle has often been criticized; but, in the authors' experience, men do not mind this, although it may be objectionable to young women. Unless the results from the Syme amputation are good—that is, the stump is capable of full end-bearing, it is well healed, has a minimum of scar, and is not tender or painful—amputation below the knee is preferable.

CONTRA-INDICATIONS

The Syme amputation should never be employed as a primary procedure after war injuries or in cases where the surgeon cannot properly supervise the postoperative care. If open wounds have been present—particularly an open amputation of the foot, as in war casualties—the operation should not be performed until the wounds are either clean or healed. Complete preoperative wound healing is not necessary for good results in experienced hands, but it is usually desirable and may be attained early by temporary skin-grafting. In the presence of open wounds, the operation should not be done until the cultures are sterile. The Syme amputation should not be performed, after the ligation of the major vessels, until sufficient time has elapsed for good collateral circulation to develop.

The Syme amputation should never be performed upon diabetic patients nor in the presence of peripheral vascular diseases, such as thrombo-angiitis obliterans or arteriosclerosis. Spina bifida and loss of sensation in the heel from injury or disease of the peripheral or central nervous system constitute clear contra-indications. The amputation should be performed only in cases in which there is enough plantar skin, with a good nerve and blood supply beneath the heel, to provide a weight-bearing covering over the cut ends of the tibia and fibula.

INDICATIONS

The Syme amputation is always preferable to amputation at a higher level, if done under the proper circumstances and if not contra-indicated in the individual case. Its greatest field of usefulness is in young men, who are otherwise in good general physical and mental condition, but who have suffered the traumatic loss of the greater part of the foot, so that the remaining stump cannot be made satisfactory for weight-bearing and locomotion either by surgery or by proper limb-fitting. Where there has been partial loss of the foot, together with a compound fracture or extensive loss of skin and soft tissue in the upper third of the leg, it is impossible to get a good below-the-knee stump; and in such a case amputation above the knee is the only alternative to the Syme amputation. These leg wounds may be treated as though the foot had not been lost, and the Syme amputation can be performed after the wounds have healed. Severe fractures in the region of the ankle and the lower third of the tibia and fibula are not uncommon in patients who have also lost most of the foot. Here, too, the fractures are treated until there is solid union; after this the Syme amputation may be performed, without regard to the presence of the fracture. Shortening of the limb from fractures above or below the knee can usually be disregarded, as the length can easily be compensated for in the fitting of the prosthesis. A

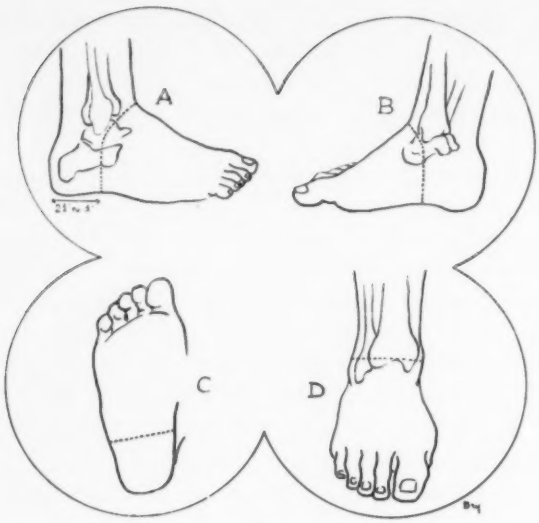

FIG. 1

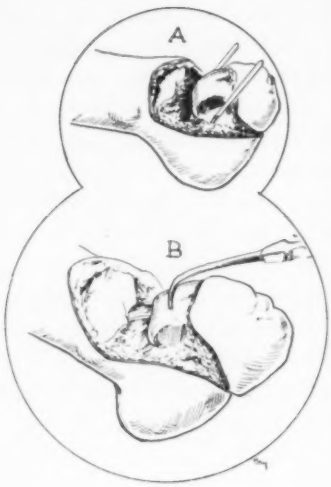

FIG. 2

Fig. 1: The line of incision for the Syme amputation.

Fig. 2: *A*: All soft-tissue structures are divided in the line of the skin incision, down to the bone. The ankle is dislocated forward by cutting the talofibular and calcaneofibular ligaments from the inside of each malleolus. *B*: In short foot stumps the bone hook is then inserted into the talus to facilitate pulling the parts forward, while the calcaneus is dissected extraperiosteally out of the heel flap.

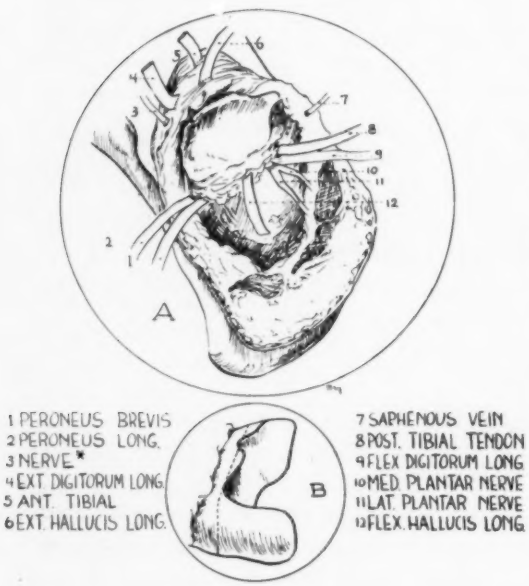

FIG. 3

Fig. 3: *A*: After the calcaneus has been dissected out extraperiosteally, the malleoli are exposed and sawed off. *B*: The saw line is placed as far distally as possible, and usually some of the articular cartilage on the end of the tibia is left. (See Fig. 4, *A*.)

* Superficial peroneal nerve.

good Syme amputation may be done if as little as one inch of good plantar skin is left on the heel. It may be performed for loss of the fore part of the foot, due to frostbite, trench foot, freezing, or any combination of these injuries, provided, first, that sufficient time has elapsed for the local circulation to be reestablished and, second, that persistent tenderness is not present in the soft-tissue covering of the heel, which is to be used for the end-bearing flap. It may also be used advantageously in certain cases of unilateral and bilateral congenital deformity, with marked shortening and disability.

PREOPERATIVE CARE

Proper selection of cases for the Syme amputation and judicious timing of the operation are the two most important preoperative considerations. When done after trauma, the extremity should be surgically and bacteriologically cleaner than for any other amputation. Temporary skin-grafting may shorten the period before operation, but is not always necessary. Roentgenograms should be taken in all cases, because unsuspected skeletal injuries frequently exist, particularly in war injuries. If oedema is present, it should be relieved by bed rest, elevation, wrapping, and, if necessary, by novocaine block of the sympathetic trunk. In patients

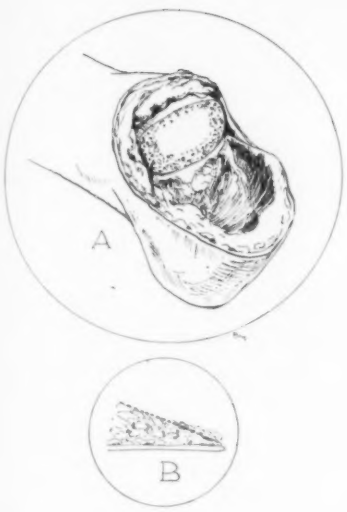

FIG. 4

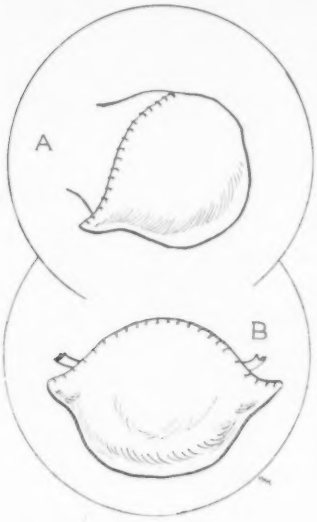

FIG. 5

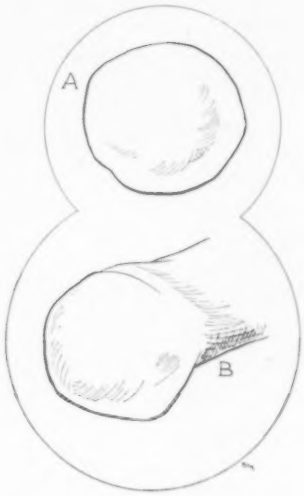

FIG. 6

Fig. 4: *A*: All tendons and nerves, except the tendo calcaneus, are pulled down, cut at the saw line, and allowed to retract proximally. The white island in the center of the end of the tibia represents cartilage. The heel flap is debrided and all muscle, fascia, periosteum, and loose devitalized strands of tissue are removed. *B*: The thick edge of the heel flap is trimmed; the sharp edge of the wedge faces anteriorly, for ease of closure. The tourniquet is then removed, and the remaining open vessels are clamped and ligated. Complete hemostasis is desirable.

Fig. 5: The heel flap is centered on the end of the leg and held there by an assistant, while the skin edges are approximated with interrupted sutures. No subcutaneous sutures are used. The stump is usually drained, as indicated in *B*, unless the foot has been clean and absolute hemostasis has been obtained. The lateral projections of skin, forming "ears", are never trimmed.

Fig. 6: Shows the contour of the stump after operation. Final forming and shaping are achieved by wrapping with elastic bandages (see Fig. 12).

who have had ligation of the major vessels or marked vasomotor spasm and have responded to novocaine block, lumbar sympathectomy should be done. Cultures should be taken on all open wounds, and operation should be postponed until the cultures are sterile. Patients should, of course, always have complete physical and laboratory examinations. The patient's mental status should be established before operation, since the best results can be obtained only when there is reasonably good cooperation on the part of the patient. Penicillin or chemotherapy should be used routinely in all cases which have, or have had, open wounds in the vicinity of the operative site.

OPERATIVE TECHNIQUE

The operation is performed in three major steps. The routine use of the pneumatic tourniquet above the knee is recommended. The operator stands at the end of the table, with an assistant on either side. After proper surgical preparation of the limb, it is rested on a block of wood about ten inches in height. For the purpose of description, the operative technique will be described as for a right-handed operator and a right leg.

Step 1

This consists of the skin incision, dislocation of the ankle, and removal of the calcaneus.

The incision is started across the front of the ankle joint on a line connecting the two most prominent points of the malleoli (Fig. 1). It extends medially to a point just in front of the medial malleolus (Fig. 1, *B*). From this point it is continued distally across the sole of the foot in a line at right angles to the long axis of the foot. From the lateral margin of the sole of the foot, it is continued proximally to the anterior margin of the lateral mal-

leolus. From this point, it is curved gently to meet the beginning of the incision (Figs. 1, *A* and 1, *C*). The distance from the posterior aspect of the heel to the line of incision on the sole of the foot will vary from two and one-half to three inches, depending upon the size of the leg and whether or not the foot is fixed in equinus. In patients with large ankles and feet and those having fixed equinus, the incision will extend farther forward on the sole of the foot. After the skin has been incised in this manner, all soft structures are divided in the line of the incision, down to the bone. This opens the ankle joint anteriorly so that the superior surface of the talus can be seen. The scalpel, with the sharp edge downward, is then placed in the joint space between the medial malleolus and the talus; and the deltoid ligament is divided, while the cutting edge of the scalpel is kept against the tarsal bones. The calcaneofibular ligament is divided in a similar manner (Fig. 2, *A*). This allows the talus to be dislocated forward so that a large bone hook can be inserted into its superior articular surface (Fig. 2, *B*). The hook is pulled forward with the left hand, while the surgeon very carefully removes the calcaneus extraperiosteally by sharp dissection with a scalpel. The sharp edge of the scalpel is always kept against the bone so that no damage will be done to the soft-tissue structures in the heel flap. When the tendo calcaneus has been reached, it is divided near its insertion into the calcaneus. The bone hook is then removed and inserted into the posterior part of the calcaneus to facilitate forward traction, while the remainder of the calcaneus is dissected out.

Step 2

This step consists of sawing off the malleoli, cutting tendons and nerves, debriding the heel flap, and ligating the major vessels.

By means of tissue forceps, the deep layer of subcutaneous fascia, just anterior to each malleolus, is identified and a subfascial extraperiosteal exposure of each malleolus is executed by sharp dissection; the exposure extends up to the level of the articular surface of the distal end of the tibia. Soft structures are retracted on either side of the ankle, and the malleoli are sawed off squarely in a plane at right angles to the long axis of the patient's body; the portion of the posterior aspect of the tibia which projects distally to the anterior

FIG. 7

FIG. 8-A

FIG. 8-B

Types of war wounds of the feet for which the Syme amputation is most commonly performed.

Fig. 7: The short Chopart stump is fixed in equinus and the end is covered by a wide scar.

Figs. 8-A and 8-B: Skin-grafting has been done. Grafts of this type are not satisfactory on weight-bearing areas.

FIG. 9-A

FIG. 9-B

FIG. 9-C

Three views of a unilateral Syme stump, resulting from the technique described. (*Fig. 9-A is reproduced by courtesy of W. B. Saunders Company*[1].)

articular aspect is also sawed. The saw line is placed as far distally as possible, so that frequently a large area of articular cartilage may remain on the end of the tibia. The periosteum on the distal end of the tibia and fibula is left intact (Figs. 3 and 4).

Beginning with the tibialis anterior tendon and proceeding in a clockwise direction, all tendons and nerves except the tendo calcaneus are now isolated, clamped with Kocher clamps, pulled down, cut squarely off at the level of the saw line, and allowed to retract (Fig. 3). Great care must be exercised in handling the posterior branches of the tibial nerve, since it is so closely associated with the corresponding vessels. With reasonable care, these nerve branches can always be isolated without damaging the vessels. They are cut off and allowed to retract well above the cut end of the tibia. The dorsalis pedis and the medial and lateral plantar branches of the posterior tibial arteries and veins, as well as the saphenous vein, are located at the line of incision, where they are clamped and ligated. The heel flap is then debrided; and all fascia, muscle, and loose strands of devitalized tissue are removed. The abductor hallucis muscle is removed from the medial side of the heel flap and the abductor digiti quinti is removed from the lateral side. The plantar fascia and the flexor digitorum brevis are removed from the center of the heel flap. Removal of these muscles and the fascia is accomplished by sharp dissection with the scalpel. The anterior edge of the heel flap is then beveled with a pair of curved scissors so that, anteriorly, the flap is wedge-shaped (Fig. 4). The tourniquet is then deflated.

Step 3

This consists of clamping, ligating small vessels until a dry field has been obtained, closing the stump, draining, and dressing.

After the tourniquet has been removed, all the bleeding vessels are clamped and ligated with fine ties until the field is as dry as possible. As in all amputations, complete hemostasis is highly important. The heel flap is centered over the end of the stump and held there by one assistant, while it is sutured to the skin of the anterior surface of the leg. No subcutaneous sutures are used, and the resulting suture line is straight across the anterior aspect of the stump. Formerly, the heel flap was fixed to the end of the leg with from

two to four heavy, deep sutures, before the skin was closed, in order to ensure again displacement. Two rubber dams (Fig. 5) are inserted in all cases where there had pre ously been open wounds. Drainage may not be necessary in absolutely clean woun

FIG. 10

FIG. 11

Fig. 10: Roentgenographic appearance of the Syme stump, done by the technique described.

Fig. 11: Roentgenograms of a poorly performed Syme amputation; the saw line was oblique and too high. The patient was fitted with the usual type of Syme prosthesis, however; and when discharged, eight months after the original injury, had good function.

FIG. 12

FIG. 13

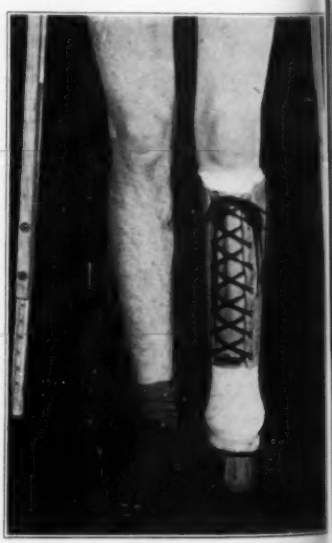

FIG. 14

Fig. 12: Proper method of bandaging a Syme stump; two four-inch elastic bandages are used.

The non-padded plaster (Fig. 13) or the brace type of pylon (Fig. 14) is used temporarily for shrinkage of the stump, while patient is waiting for the permanent prosthesis. The plaster pylon is preferable. In double Syme amputations, the ends of the temporary limbs are made flat for better balance. (*Figs. 12 and 14 are reproduced by courtesy of W. B. Saunders Company*[1].)

where complete hemostasis has been obtained. The resulting lateral projections of skin forming "dog ears" are never trimmed, as this might devitalize the flap (Fig. 5). The "dog ears" disappear later, as a result of proper use of the compression bandage (Fig. 6). The knee is then held in extension, while a compression bandage is applied over the dry gauze dressing; great care is exercised to hold the heel flap in the center of the end of the long axis of the body while the bandage is being applied. Two four-inch cotton elastic bandages are used (Fig. 12). Adhesive strips to hold the heel flap in position

FIG. 15-A

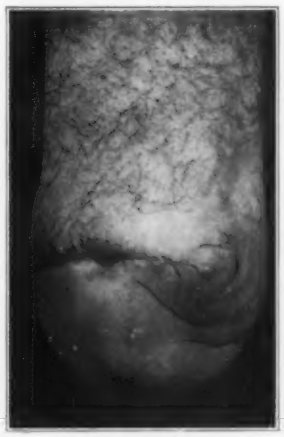

FIG. 15-B

FIG. 15-C

Close-up views of a Syme stump, several months after operation. Note that the entire weight-bearing end of the stump is covered by plantar skin, which has always been accustomed to weight-bearing.

FIG. 16-A

FIG. 16-B

The advantages of the Syme stump and of the Syme prosthesis over the below-the-knee stump and prosthesis are partly shown. (*Fig. 16-B is reproduced by courtesy of W. B. Saunders Company*[1].)

are not necessary. It is important never to apply the postoperative dressing with the knee in flexion, since discomfort will be experienced when an attempt is made to extend the knee.

POSTOPERATIVE CARE

The leg is immediately elevated on pillows, and elevation is maintained from the time the dressing is applied until the wound has healed. The patient is placed in bed, preferably one in which the entire foot of the bed can be elevated with the knee practically straight; only enough flexion is left for the comfort of the patient. The patient is not allowed to turn onto the side on which the amputation has been performed, as this tends to displace the heel flap medially. No postoperative splint is used, since the bed acts as a splint. The first postoperative dressing is changed in twenty-four hours; otherwise the blood on the dressing would dry and removal of the dressing later would be very painful. One drain may be removed at this time if the stump seems dry; but, if there is serosanguineous discharge, both drains are left in place for as long as seven days. The dressing thereafter is changed as indicated,—usually about every forty-eight hours until both drains have been removed, which may be within from two to seven days after operation. No further dressing is done until the fourteenth day, when the sutures are removed. Penicillin or chemotherapy, if used, is discontinued after healing has been assured; this is usually between the seventh and fourteenth day after operation. After the sutures have been removed, the foot of the bed is leveled, and elevation of the extremity is discontinued. The limb is not allowed to hang down until the end of the third week after operation. If the circulation to the heel flap is threatened during the postoperative period, novocaine blocks of the sympathetic trunk are carried out while the patient is in bed. Drains should not be removed until sympathetic blocks have been discontinued, as there may be gross bleeding into the stump if the sympathetic blocks are effective.

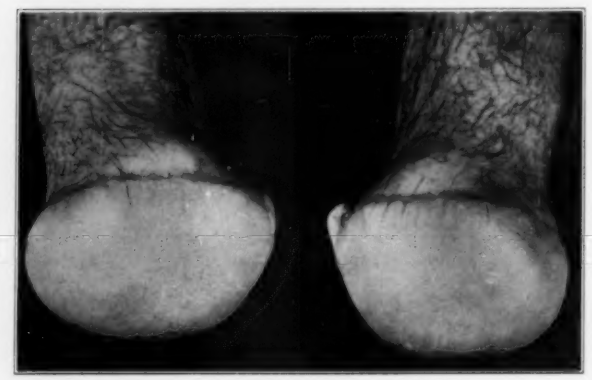

FIG. 17-A

FIG. 17-B

A bilateral Syme amputation, without and with the prostheses. Both amputations were performed at the same time, and primary healing occurred in two weeks. (*Fig. 17-B is reproduced by courtesy of W. B. Saunders Company*[1].)

Ordinarily, a walking pylon is applied between the third and fourth week (Fig. 14). A non-padded plaster with a crutch-tip type of extension is preferable. Patients start weight-bearing on the pylon with crutches for the first week, after which they usually walk with full weight-bearing, without support. After the plaster pylon has been used for about four weeks, a plaster mold of the stump and leg is taken for the permanent prosthesis. In order to make the plaster mold, it is necessary to remove the first pylon; after this a second one is applied, which is worn with active weight-bearing until the permanent prosthesis is ready for use. It requires only a few days after the permanent limb has been applied for

patients to change from the style of walking associated with a peg leg to the normal heel-and-toe gait.

COMPLICATIONS

In this series of seventy-five cases, complications have occurred in approximately 10 per cent. Most of the complications were of a minor nature; but in three cases revision was necessary, following infection or sloughing of part of the heel flap. In no case has reamputation at a higher level been done. Infection has often followed hematoma formation; when hematoma was prevented, infection did not usually occur. Hematoma has also occasionally caused sloughing of a small edge of the heel flap, ordinarily on the medial aspect; but this usually has not required revision or altered the patient's course materially.

Displacement of the heel pad medially or redundancy of the pad has not occurred in any case to an extent sufficient to interfere with good function or to cause dissatisfaction on the part of the patient or the surgeon. There has not been a single instance of phantom limb or of a painful nerve syndrome.

With increased experience, the incidence of complications decreased, so that they rarely occurred in the last 75 per cent. of patients in this series.

RESULTS

No long-time follow-up study has been possible, since the first patient in this series was operated upon only three years ago. However, every patient was followed very carefully until he was fitted satisfactorily with a limb, trained to use it, and either separated from the Service or returned to duty on a limited service status. A few patients are still in the hospital, but all of them have stumps as good as those of the patients who have been discharged. In all of these cases the immediate results have been completely satisfactory to the patient and to the surgeon.

The stumps have all fulfilled the following requirements, which are essential for good functioning of a stump after the Syme amputation:

1. It should have good circulation and good sensation.
2. It should be painless and non-tender.
3. It should be capable of full end-bearing, with or without a prosthesis.
4. It should be suitable for fitting in the conventional way with a prosthesis which requires no apparatus above the knee.
5. There should be no tender scars or other areas liable to break down from the use of a prosthesis.
6. It should be satisfactory both to the patient and to the surgeon.

SUMMARY

The Syme amputation has not in the past been fully utilized by most surgeons in this country. A Syme amputation which meets all the requirements of good function is the best major amputation in the lower extremity. As such, it has definite advantages over amputation below the knee and over most short foot stumps.

The chief disadvantage is the degree of skill and attention on the part of the surgeon, which are required for the best results. If the Syme amputation does not meet the requirements of good function, or if it cannot be made to do so, amputation below the knee is preferable.

The preoperative indications, the operative technique, and the postoperative care are equally important. It is unfortunate that such a small proportion of patients requiring amputations of the lower extremity have the preoperative indications for this procedure, but the experience gained in observing this group of patients has convinced the authors of the superiority of the Syme stump over other stumps of the lower extremity.

It is recommended strongly that the Syme amputation be performed, whenever possible, instead of the more widely accepted mid-leg amputation.

REFERENCES

1. Alldredge, R. H.: Indications for the Syme Amputation. Surg. Clin. North America, **26**: 422–431, Apr. 1946.
2. Wilson, P. D.: The Syme Amputation. Surg. Clin. North America, **1**: 711–728, 1921.

DISCUSSION

Lieutenant Colonel Harry D. Morris, Medical Corps, Army of the United States: I want to compliment Lieutenant Colonel Alldredge on his excellent presentation of a difficult surgical technique. I wish to emphasize again that almost universally, in Army Amputation Centers, a good Syme stump is considered the best result of major lower-extremity amputations, and that much of the criticism in the past has been brought about because of poor selection of cases or faulty operative technique. Our own experience is based on some forty-two cases which have been done at our Center during the past two years. Colonel Alldredge has pointed out very definitely the indications for the proper selection of cases in which to perform the Syme amputation. Violation of these clear-cut principles will lead to unsatisfactory results—as is true of any other operative technique—and will bring discredit to the operation. Some criticism in the past has been directed toward these end-bearing stumps, because of the difficulty of prosthesis fitting. Our experience has been essentially that of the authors,—namely, that a Syme prosthesis can be constructed more easily and simply than can a standard below-the-knee prosthesis, and it requires considerably less adjustment. The patient is happy because he does not have any apparatus extending above the knee, and pelvic belts can be eliminated.

We have had no bilateral Syme amputations, but we have had several Syme amputations in combination with a below-the-knee stump on the opposite leg. Invariably the amputee will state that he feels the Syme is the more satisfactory stump to take the greater part of his weight and thus to relieve the opposite stump.

It might be of interest to mention a variation in operative technique that we have used in Syme amputations at McCloskey General Hospital for the past one and a half years. The subperiosteal resection of the calcaneus has been used by Gordon Dale at the Christie Street Hospital for some time; and, following Dale's advice, we have used this technique in the last twenty-eight Syme amputations. We have been impressed with the fact that, for an operator who is relatively inexperienced in the Syme technique, there is probably less danger of injuring the blood supply of the flap by subperiosteal than by extraperiosteal dissection of the calcaneus, and that the flap adheres very rapidly to the tibial end. In from seven to ten days, it is almost impossible to shift the flap; and, by using a relatively simple postoperative dressing of adhesive strips, we have had no difficulty with shifting of the flap, and the postoperative care has been rendered quite simple. One is concerned, on viewing a postoperative roentgenogram, as to the fate of this large mass of calcified tissue which remains at the stump end; but patients who have been followed for a year have had no particular complications from this source. One must be careful, however, to trim the periosteum around the margins of the flap in order to prevent proliferation; this might possibly make some painful areas, which would give pressure on the sides of the prosthesis.

I believe it is a rather universal feeling on the part of those who have had considerable experience with Syme amputations that the merits of this particular amputation have not been fully appreciated by the profession at large; and that, if proper selection, meticulous operative technique, and adequate postoperative care are carried out, the Syme amputation will find its proper place.

Dr. William E. Gallie, Toronto, Ontario, Canada: I have listened to this paper with the greatest pleasure and I rise now solely to commend the writers for what they have said and to support them in their advocacy of the Syme amputation. Reporting, as they do, nearly a hundred operations done within three years, there isn't anybody who has had more experience with the technique or had a better opportunity to study the early results. Later on, they will be equally competent to report the late results; but in the meantime I can assure them that their hopes are well founded, for it has been the experience of the Toronto group, whom I represent, that the men with Syme amputations walk better, stand up better, and have more comfort and general satisfaction with their artificial legs than men with any other kind of amputation of the lower limb.

The moving picture [shown by the speaker] was prepared for me by my colleagues at the Christie Street Hospital in Toronto. It demonstrates a group of these patients, whose amputations were performed from two to fifty years ago, walking and jumping from a height. The patient whose amputation was performed fifty years ago is an old friend of mine who has played hockey and football, and became one of the leading Canadian cricketers. He put me out of the quarter-finals in the University Club squash racquet tournament, thirty-five years ago.

CONSERVATION OF SHORT AMPUTATION STUMPS BY TENDON SECTION *

BY LIEUTENANT COLONEL HARRY C. BLAIR AND LIEUTENANT COLONEL HARRY D. MORRIS
Medical Corps, Army of the United States

The purpose of this presentation is to describe two surgical procedures which have proved of value in conserving competent function in short amputation stumps.

At McCloskey General Hospital, one of the seven large Amputation Centers set up by the Surgeon General's Office, almost daily the decision must be made as to the necessity of sacrificing short stumps of the leg and forearm because it is impossible to fit prostheses to them. Patients, on the other hand, do not want to lose the power to use their elbows or knees, as the case may be. To aid in this reasonable desire, two surgical procedures have been developed: section of the biceps tendon in the upper extremity, and section of the medial and lateral hamstrings in the lower extremity.

A thorough search of the available literature reveals mention of these procedures in only one instance. In "The Medical Department of the United States Army in the World War", the following brief statement is made: "In these cases [that is, short below-the-knee amputations] the leverage may be increased to the point of utility by removing the fibula, cutting away practically all of the muscular tissue on the back of the stump and severing the inner hamstring". No mention is made of section of the biceps in amputations of the upper extremity.

The stump length of the forearm is measured, according to Kirk, "from the insertion of the biceps tendon, which stands out well when the forearm is flexed at right angles against resistance, to the bone ends of the stump. This gives the true stump length. The minimum stump length allowing the fitting of a forearm prosthesis and furnishing enough leverage to activate it is one and one-half inches." The authors have found that, by excising one inch of the biceps tendon at or near its insertion, approximately two inches in length of useful stump is gained. Following this operation, the true stump length is measured from a point at or near the coronoid process of the ulna.

A functional stump length of one and one-half inches below the knee joint is usually considered the shortest which will allow proper fitting of an artificial limb. The hamstrings, particularly the medial hamstrings, insert at or below this level. Excision of the hamstrings allows a gain of approximately two inches of usable stump length. It is hardly necessary to state that the ability to use a forearm or leg stump, however short, greatly increases the usefulness of the extremity; and any procedure designed to aid in this ability is worthy of consideration.

As stated previously, when the elbow is flexed against resistance, the biceps stands out. Similarly, when the knee is flexed, the hamstrings become prominent. The effect is to crowd the prosthesis off the short

FIG. 1

Schematic illustration of surgical section of biceps tendon. Note increased functional length of stump.

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

FIG 2-A
Postoperative roentgenograms of short below-the-elbow stump.

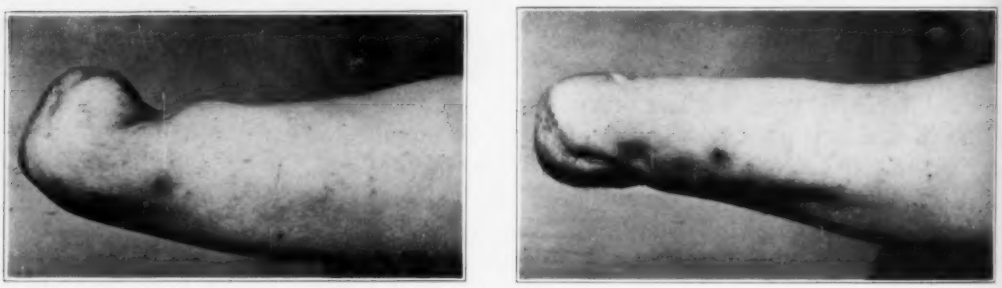

FIG 2-B
Patient illustrates range of motion after operative section of biceps tendon.

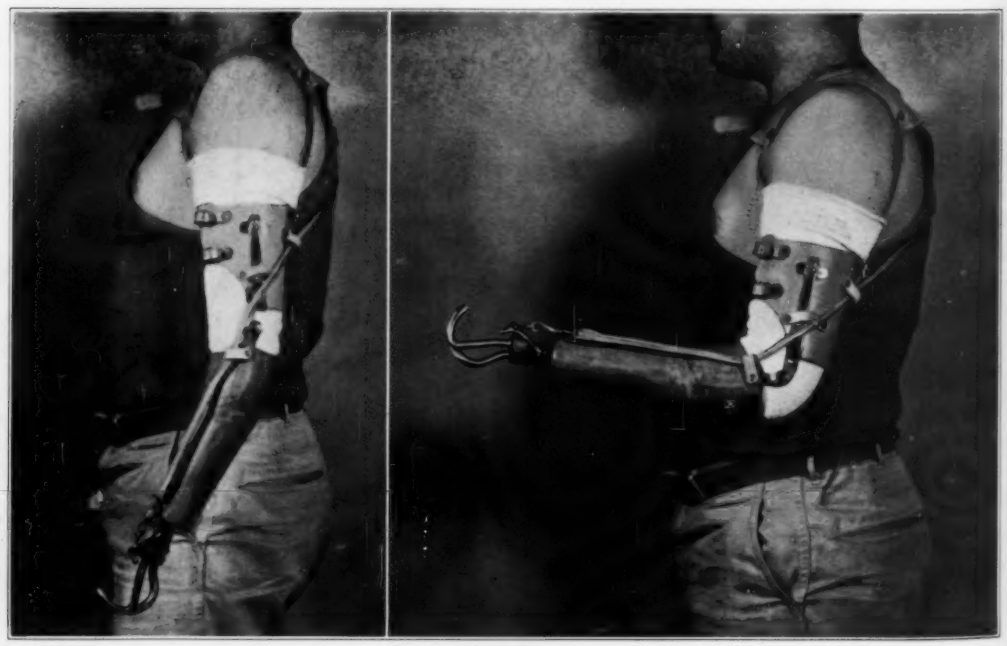

FIG. 2-C
Patient has been fitted with standard prosthesis.

stump; this inhibits the use of the prosthesis in flexion, especially in the upper extremity. Thus the most important movements, which aid in eating, dressing, and shaving, become impossible.

The insertion of the biceps is approximately two inches distal to the coronoid process of the ulna and about the same distance from the elbow joint itself. The biceps muscle, of course, is primarily a supinator of the forearm, and the brachialis is the prime flexor of the elbow joint. The brachialis, being inserted into the coronoid process, is placed close to the anterior surface of the humerus, and extends only a short distance (perhaps one-half inch) onto the stump. Loss of the biceps may decrease the power of flexion slightly, but this is not of material importance. Likewise, loss of rotation of the forearm is of no impor-

FIG. 3-A

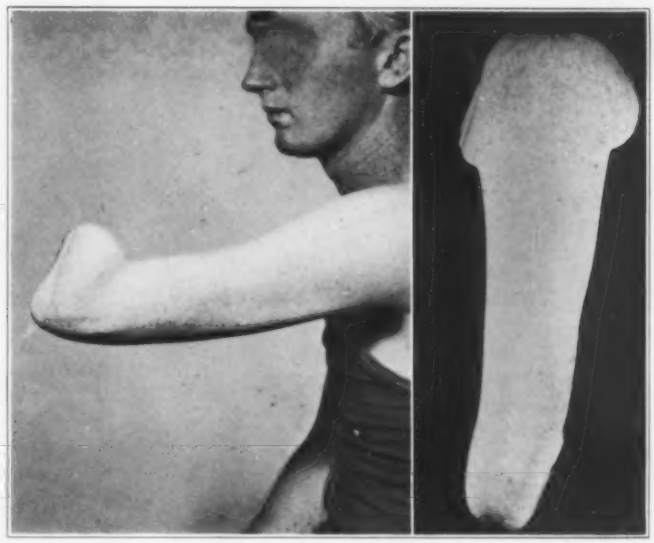

FIG. 3-B

Fig. 3-A: Roentgenogram, taken after section of biceps tendon.
Fig. 3-B: Postoperative photographs of stump, following plastic revision and section of biceps tendon.

FIG. 3-C

Patient has been fitted with prosthesis. Note double Northrop cable control and patient's ability to open hook at level of mouth.

tance at this level. A patient with a short stump will not be able to do heavy work, because of the loss of leverage.

At the knee, the hamstrings are the chief flexors and rotators, and their loss does

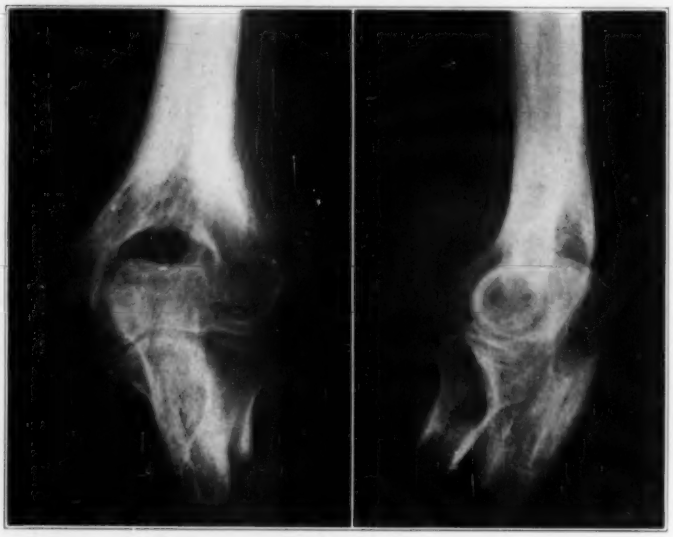

Fig. 4-A: Roentgenograms of short forearm stump, following section of biceps tendon.

Fig. 4-B: Photographs taken after plastic revision and section of biceps tendon.

Fig. 4-C: Patient has been fitted with plastic below-the-elbow prosthesis.

FIG 4-A

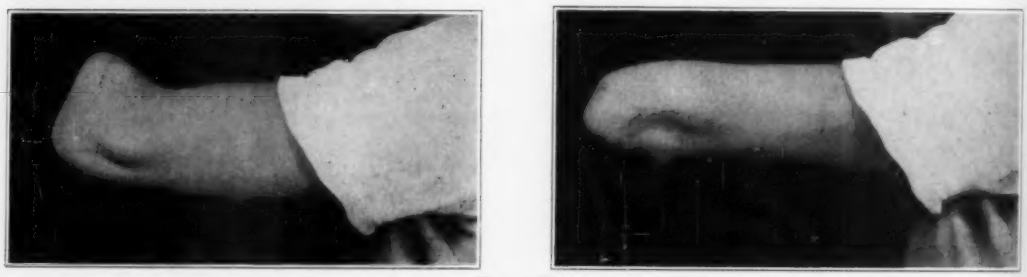

FIG. 4-B

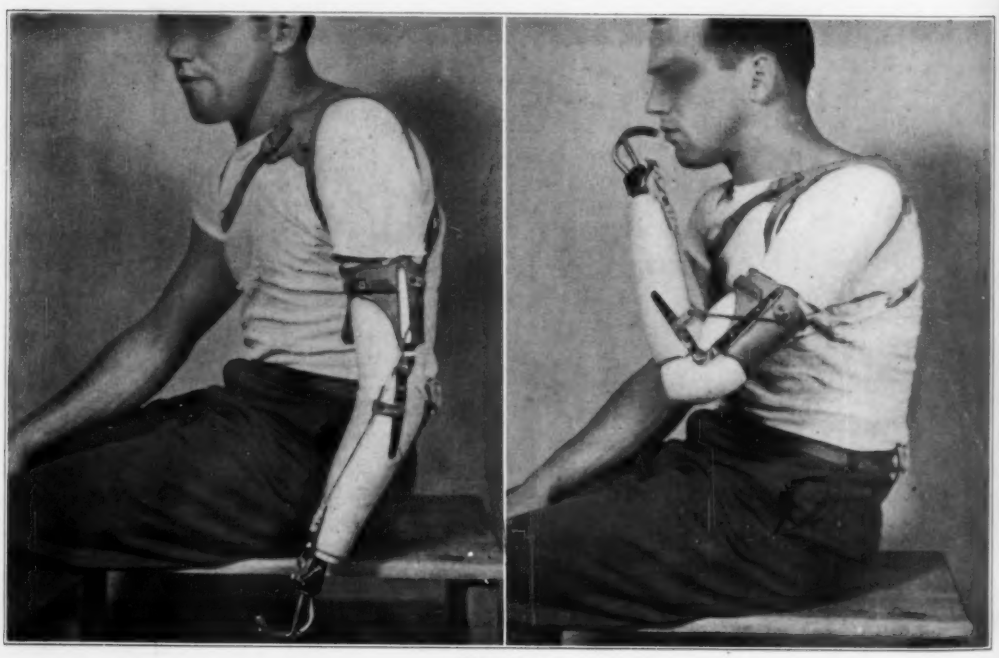

FIG. 4-C

weaken this power. It is conceivable that removal of these important muscles would lead to hyperextension of this joint, which obviously would be the cause of a serious disability. In none of the cases treated by the authors has hyperextension shown any tendency to occur. With the use of a prosthesis, extension with power is the major necessity, as this allows the patient to stand and to bend his prosthetic knee at any angle, while bearing full weight. The power of flexion is of minor importance. The weight of the prosthesis itself will carry out this movement. The two heads of the gastrocnemius arise from the lower condyles of the femur, and this muscle acts as an accessory flexor of the knee joint. In a short-leg amputation, the gastrocnemius is attached to the lower end of the stump, and this acts as the point of insertion. The gastrocnemius also prevents hyperextension of the knee joint when the hamstrings are removed.

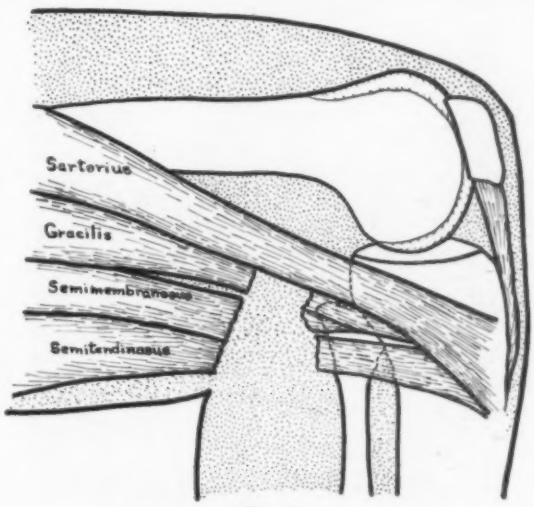

FIG. 5

Schematic drawing illustrates operative section of hamstring tendons. Note increased length of functional stump obtained (one and one-half to two inches in the average patient).

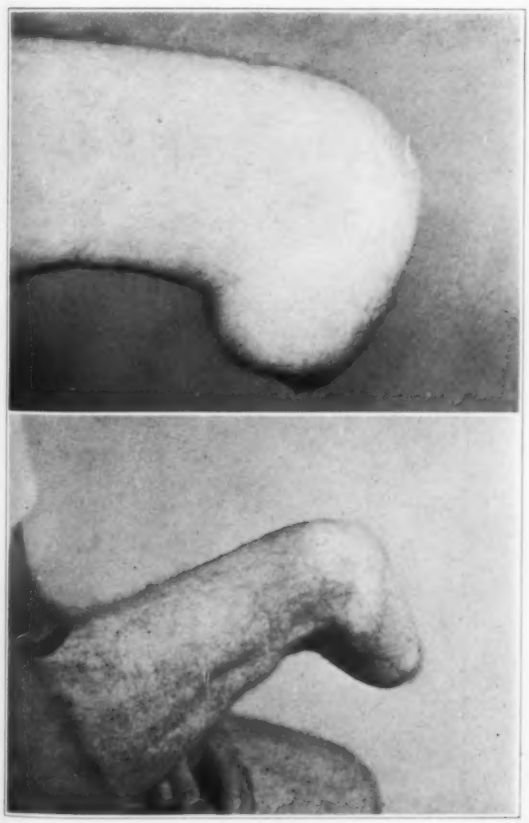

FIG. 6-A

FIG. 6-B

Fig. 6-A: Photographs of short below-the-knee stump taken before and after operative section of hamstring tendons. Note the increased functional stump length obtained, which allows fitting of prosthesis.

Fig. 6-B: Patient has been fitted with standard Army provisional prosthesis.

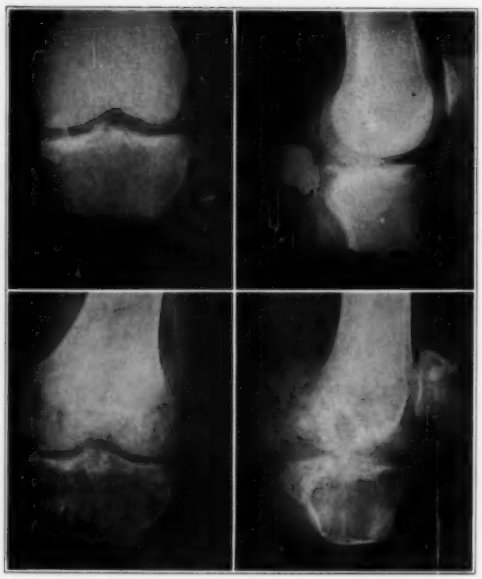

FIG. 7-A

FIG. 7-B

Fig. 7-A: Roentgenograms, before operation (upper) and after operation (lower), of short below-the-knee stump. At operation the remnant of the fibula was excised and the hamstring tendons were sectioned.

Fig. 7-B: Photographs taken after revision of stump and section of hamstrings.

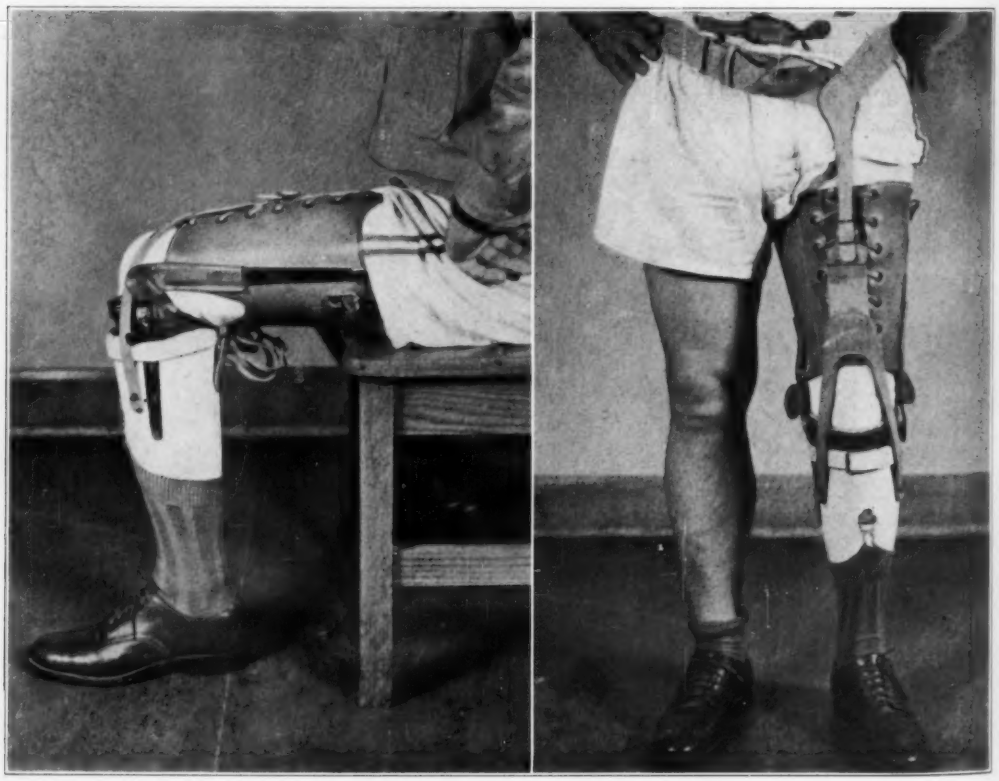

FIG. 7-C

Patient has been fitted with prosthesis; a slip-socket was used in this case. There is no difficulty with stump rising out of the socket during flexion.

OPERATIVE TECHNIQUE

At the time plastic revision of the short forearm stump is undertaken, the terminal scar is excised and equal anterior and posterior flaps are established. By undermining the anterior flap, the insertion of the biceps tendon can easily be found and can be severed at its point of attachment to the radius. The tendon is then pulled down with an Ochsner forceps, and approximately one inch of the tendon is excised. This allows the remainder of the tendon to retract proximally so that it will not become reattached. Any redundant muscle which remains on the lateral aspect of the stump—chiefly the brachioradialis—is thinned down or excised in order to decrease the bulk of the stump and allow a minimum of soft tissue to remain. The investing fascia of the muscle, if present, is sutured over the bone end. If fascia is not available, skin only is sutured over the end of the bone. Drainage is employed for forty-eight hours if complete hemostasis cannot be secured.

In the short-leg stumps, the fibula is excised routinely during plastic repair; the biceps femoris tendon is severed from its insertion at this time. Without any further procedure, it retracts far enough to accomplish the desired purpose. The medial limb of the incision used in shaping the flaps is carried sufficiently high to section the semitendinosus, semimembranosus, and gracilis tendons, so that they are allowed to retract. If extension of this medial incision will endanger the blood supply to the flaps, a small, separate transverse incision is made in the fold of the popliteal space; and the same tendons are sectioned through this incision. The authors have not found it necessary to section the sartorius in any case. In a few patients who had had earlier plastic repair without section of the hamstrings, the medial hamstrings have been cut at a second operation, by the technique described.

RESULTS

During the past ten months, the authors have carried out the procedures described on ten short forearm stumps and twenty-two short below-the-knee stumps, including one patient who had had a bilateral amputation. Only one patient has required reamputation at a higher level; he had a below-the-knee stump with a severe flexion contracture, which was unrelieved by surgical or conservative treatment. All the other patients have been fitted satisfactorily with provisional prostheses.

REFERENCES

KIRK, N. T.: Amputations. In Lewis' Practice of Surgery, Vol. III, Chap. X. Hagerstown, Maryland, W. F. Prior Co., Inc., 1945.

The Medical Department of the United States Army in the World War. Vol. XI. Part 1, p. 734. Washington, Government Printing Office, 1927.

THE OVERSEAS TREATMENT OF COMPOUND FRACTURES OF THE LONG BONES *

BY GEORGE O. EATON, M.D., BALTIMORE, MARYLAND

The island-hopping Pacific war, from the Southern Solomons to the Ryukyu chain, was a new type of warfare for the United States forces. Methods and implements of warfare had to be developed or redesigned to meet the new demands. The Medical Corps was no exception,—its mission was the same as in previous conflicts, but the clinical management of the patient had to be adjusted to the ever-present need for evacuation to the rear and to the type and duration of travel. As evidence accumulated and experience increased, hitherto standard procedures gave way to improved techniques. Ideal surgical management of the patient was always in conflict with the function of administration, whose mission it was to evacuate patients so that beds in forward areas were available for emergencies and so that forward units were always kept mobile. Intelligent coordination between professional activities and administrative functions was vital to the best interests of the patient. In the early treatment of battle fractures, no single doctor or group of doctors was actually in charge of the case. The patient received first aid, then was moved toward the rear; shock therapy, débridement of wounds, and immobilization of fractures was accomplished; the patient was moved by stages farther to the rear; and the clinical control of the patient changed hands with each move. Even at the Base Hospital in the overseas theater, the surgeon was in charge of the patient only until it was feasible to evacuate him to the United States. The planes or ships which carried troops and supplies forward were utilized to carry patients to the rear, so that evacuation of patients had to be coordinated with the many other demands on the facilities of the transportation organization. It was necessary to bear in mind always that transportation in the combat area would probably cause a variable degree of deterioration of the patient's general and local condition.

The initial treatment of the battle fracture had three objectives, which, in order of importance, were: the treatment of shock, the management of the wound, and the immobilization of the fracture.

Human blood plasma was available as far forward as the battlefield itself. As a replacement for blood lost by hemorrhage, it was vastly superior to the various intravenous fluids used in World War I; and the comparative ease with which it could be stored, transported, and administered greatly widened its scope of usefulness. During World War II, transfusions of whole blood gradually replaced plasma in the treatment of shock, except in the case of burns or severe crushing wounds. It became common to use as much as four or six liters in a single case. The blood flown from the United States was administered to the patient in Luzon five or more days after it had been drawn from the donor. The blood was packed so that it could be administered just as simply as plasma. Serious transfusion reactions were rare. In one reported series of 750 consecutive transfusions, using blood flown from the United States, there were no deaths, no serious reactions, and only three moderate reactions. Such complications as jaundice, anuria, and oliguria, which have been reported after the injudicious use of large amounts of whole blood, were not observed by the writer. Other measures to combat shock, such as elevation of the foot of the cot, maintenance of body heat, and immobilization of the fracture, were carried out routinely.

After first aid and shock therapy had been administered, the patient was moved to the clearing company from the Battalion Aid Station. Here the soldier had his first opportunity for operative surgery, which, in the case of a compound fracture, was débridement.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

In war surgery, débridement is aimed especially at the prevention of anaerobic cellulitis and clostridial myositis. One seldom saw gas gangrene, except in wounds involving large masses of muscle and in those in which the wound had been allowed to seal over the tract of the missile. To be effective, débridement should be carried out early and should be adequate; and at all times certain axioms must be obeyed: Adequate exposure is necessary to explore all tissues traversed by the missile, to excise all devitalized tissue, and to decompress and aerate the wound; generous incision and relaxation of the fascial layers are necessary to expose devitalized muscle satisfactorily; the excision of skin is held to a minimum; counterincisions for dependent drainage are indicated, especially in the thigh; fragments of bone which are completely detached from periosteum or muscle are excised; and severed tendons or nerves are not resutured during débridement, but only marked for future identification by means of silk or wire ligatures. Débridement in war surgery differed from that in civilian surgery in that it was necessary to lay great emphasis upon leaving the debrided wound wide open. Bleeding points were ligated, but not even partial closure of wounds of the extremities was indicated or justified. In spite of the experience gained in World War I, this lesson had to be learned all over again in the early part of this War. Patients admitted more than forty-eight hours after being wounded were not subjected to débridement, unless evidence of active infection was demonstrated. The relative comfort of a limb which had been adequately debrided, as compared with a similar wound which was under a regimen of watchful waiting, was noted repeatedly.

Local chemotherapy was first used on a large scale in this War. Each soldier was given a packet of sulfanilamide crystals to sprinkle in his wound and a supply of tablets to take by mouth. Following débridement, the application of sulfonamides to the surface of the wound was recommended. Since military surgery permits no experimentation, it was not possible to estimate accurately the value of the local application, because oral administration was employed concurrently. When penicillin became available, the value of its use locally was unproved because of the concurrent parenteral administration. Certainly, progress in wound management has veered away from the introduction of any chemical agent into a wound for its supposed antiseptic effect. Mechanical irrigation of a wound with saline solution or sterile water continues to be a good surgical practice.

One of the most important advances in war surgery has been the extensive adoption of the surgical procedure known as secondary wound closure, which was practised during the closing months of World War I. The optimum time for secondary closure is from four to twelve days after débridement, and the patient must have arrived at a hospital where bed care could be assured for at least fifteen days. Because of these prerequisites, it was not often possible to carry out the procedure in the Pacific Theater. In the Mediterranean Theater and the European Theater, where facilities were greater and distances shorter, this technique was developed. When the patient arrived at the hospital, the original post-débridement dressing was removed in the operating room, under aseptic precautions. If the débridement had been adequate, all superficial wounds and many deep wounds could be closed by secondary suture; following this the part was immobilized, preferably by a plaster cast. The conditions which most often jeopardize results are: dead tissue in the depths of the wound, with purulent drainage; too early motion; and unrecognized foreign bodies adjacent to the wound. Secondary wound closure has been reported successful in 85 per cent. of cases which were properly chosen. Bacteriological studies of wound flora have not proved useful in selecting cases for secondary closure. The great value of secondary wound closure in compound fractures is the minimizing of scar-tissue formation, adjacent to a healing fracture.

Lumbar and thoracic sympathetic block with procaine was utilized to an increasing extent in forward areas for the control of vasospasm following injury. Frequently during débridement the main artery, such as the brachial or popliteal artery, would be observed to be intact, but contracted and pulseless. Following débridement, sympathetic block

would be accomplished and would be repeated daily, if indicated, until warmth and pulsation returned to the distal portion of the extremity. The extreme value of this procedure in such cases should always be kept in mind.

Statistics show that 68 per cent. of battle wounds involve the extremities, and that about half of the extremity wounds result in fracture, so that about 34 per cent. of battle wounds are compound fractures. These battle fractures differ from the usual civilian fracture in several important ways: They are usually markedly comminuted, due to the high velocity of impact. There is usually extensive soft-tissue damage. The tendency to shortening and overriding is much less than in simple fractures. The time of healing (formation of callus) is prolonged, and the time interval in which reduction of displacement can be accomplished is extended.

On the battlefield, splinting of long-bone fractures was part of the routine first aid. The upper extremity was usually bound firmly to the chest wall; traction splints were seldom used. The thigh and leg fractures were placed in traction in an Army leg splint, if available; if not, they were splinted to any rigid material at hand, such as boards, tree limbs, or rifles. At the Battalion Aid Station, such improvised splints would be replaced by the Army leg splint. This is a Thomas splint in which the metal ring has been replaced by a soft, pliable leather, which forms the posterior half of the ring, and by a strap and buckle, which form the anterior half. Adjustment of the strap and buckle so that the posterior part of the ring would not slip up over the ischium, and yet so that there was no impediment to return circulation at the groin, was extremely difficult. Periods of travel were comparatively prolonged, and plaster was substituted for immobilization as soon as the wound had been debrided. In order to save time and manpower, compound fractures of the femur were debrided with the limb in traction on a portable fracture table,—either the commercial type or an improvised imitation. In this way, general alignment and the full length of the bone could be restored; this was the goal in reducing the fracture, at this stage.

Plaster immobilization consisted of a "one and one-half" hip spica, which extended from the costal margin to the knee on the sound side and to the base of the toes on the injured side. The cast was reinforced with a strut and was well padded and split. In our hands, the Tobruk splint was unsatisfactory. Fractures of the lower part of the femur which could be immobilized in a Tobruk splint could as well be immobilized in a toe-to-groin cast. In so far as possible, traction casts were not used during transportation. All compound fractures above the elbow joint were immobilized, after débridement and general realignment, in shoulder spica casts, with the upper arm in from 20 to 40 degrees of abduction. The hanging cast proved to be totally ineffective and uncomfortable. Compound fractures of the other long bones, after débridement, were immobilized in padded plaster casts which included at least the joint above and the joint below the fracture. Because of the hazard involved, the skin-tight plaster technique was not used during transportation.

The journey to the Base Hospital was begun by the patient with a compound fracture after shock therapy had been completed, the wound had been debrided, and the fracture immobilized. In the early days of the New Guinea campaign, the distance was about fifteen hundred air miles and might be made by ship or plane, with numerous stops and ambulance rides *en route*. Stops would be made at military hospitals, and a tendency developed to change the cast at each stop in order to observe and report the condition of the wound. For this reason, the rule was made that a patient would not be subjected to change of cast if his temperature was normal, his injured limb was comfortable, and the circulation in the toes or fingers was normal. This rule proved to be satisfactory and practical. All patients with compound fractures had a normal expectancy of not returning to duty within four months, and were therefore destined to complete their convalescence in the United States. They were evacuated to General Hospitals in rear areas for treatment until they could be evacuated from the Pacific Theater.

The General Hospital was especially equipped and staffed to investigate diagnostic problems and to deal with therapeutic problems. A critical estimate was made of the patient's general and local condition, and an accurate history was culled from his records. Casts were removed and the wounds were revised and closed secondarily, if feasible; or further débridement was performed, if indicated. At this Hospital, the choice of methods for definitive treatment of the fracture was made. Open reduction and fixation were usually reserved for those cases in which attempts at closed reduction had failed. Patients with fractures of the arm, forearm, or leg continued their convalescence in padded plaster casts, provided that, by manipulation or by wedging, satisfactory reduction could be obtained and maintained. Traction, when indicated, was usually of the skeletal type. Distraction of the fragments was apt to occur with the weight values usually used in simple fractures. External skeletal fixation was seldom used, perhaps because the apparatus was scarce, or perhaps because immobilization of soft-tissue wounds speeded up healing and diminished the tendency for spread of infection.

A series of thirty-five cases with fractures of the femur, admitted to a General Hospital in the Pacific area, have been reported by Hochwalt, Rogers, and Culmer.[1] The average time which elapsed between injury and admission was twenty-five days. Ten patients were in satisfactory positions in plaster and were not disturbed. Nine patients had simple fractures with malposition; and, in eight of these, open reduction was necessary to secure satisfactory positions. Sixteen patients had compound infected wounds with malposition, and in all of these the fractures could be reduced satisfactorily by skeletal traction. This illustrates well the statement that the compound fracture received in battle has less tendency to become displaced in plaster, and a longer time interval exists within which closed reduction of the displaced fragments can be accomplished. General Kirk strongly favored the routine use of balanced traction for fractures of the femur. If the patient arrived with the fracture fragments in good position in plaster, no change was made until consolidation of the fragments had occurred. When traction was indicated to correct malposition, skeletal traction applied through the tibial crest appeared to be the most satisfactory. When traction was indicated to maintain full length, the Russell-Hamilton suspension traction proved to be adequate, if the skin areas were available. While patients with fractures of other long bones could be evacuated to the United States promptly without risking the occurrence of displacement of the fragments in plaster, it was necessary to keep patients with fractures of the femur under treatment overseas until sufficient healing had taken place so that malposition would not develop after transfer to a plaster cast. This period varied from eight to sixteen weeks.

Statistics of World War II will show a marked improvement over those of the last War in the rate of survival and the escape from permanent crippling disabilities, subsequent to war wounds of the extremities. This improvement will not be primarily the result of advances in chemotherapy, but rather of advances in shock therapy and in wound management. Further improvement is possible. The administration of the Medical Corps must take a more active interest in the clinical welfare of the patient. The visit of the Surgeon General to the Pacific Theater in the early months of 1945 was a most powerful and pleasant stimulus to the average professional medical officer. Here was the highest ranking medical officer in the Army of the United States on a tour of inspection, making clinical bedside rounds and giving helpful instruction and criticism to the ward officer. The consultant system, begun in World War I and enlarged in this War, is the key to improving the quality of medical service rendered the patient. Particularly in the more forward areas, the average young surgeon is loaded with more responsibility than he has been trained to assume. He is notably conscientious and anxious that his patient should receive the best possible treatment. He is unable to follow the patient's progress after evacuation. Circulars and memoranda have a way of not reaching him. Only by the visits of consultants can he learn of his errors and of new methods and procedures. Military surgery has

made great strides, but even more progress will be made if more emphasis is placed upon the quality of professional accomplishment.

1. Hochwalt, W. R.; Rogers, S. C.; and Culmer, A. E., Jr.: Fractures of the Femur. Bull., U. S. Army Med. Dept., No. 88, pp. 86–90, May 1945.

DISCUSSION

Dr. Edwin F. Cave, Boston, Massachusetts: During the early months of the campaign in the Pacific, the care of compound fractures was not the best,—not because of neglect on the part of the Medical Corps, but because of the small number of adequately trained medical personnel available in the Theater, because of the lack of transportation, and the great distances of fixed hospitals from the areas of combat.

When evacuation of patients by air became more efficient in late 1943, 1944, and 1945, no longer did we receive at our General Hospitals malnourished, exhausted, and dehydrated patients, many of whom had malaria and septic compound fractures,—a situation frequently encountered during the early New Guinea campaign. Due to air evacuation, particularly from the Philippine battles, patients came to General Hospitals within a few days. All were reasonably well nourished; their blood losses were not great. Their wounds had been well cared for, and plaster immobilization had been well applied. Malaria was a much less frequent complication.

Upon arrival at the General Hospital, every "battle fracture" was seen promptly by a ward officer. He evaluated the general condition of the patient: for evidences of sepsis or blood loss; his state of nutrition and dehydration; and also the condition of the injured extremity,—its circulation, motion of the toes or fingers, and evidence of local sepsis.

If there was evidence of local sepsis or of circulatory difficulty, the patient was taken immediately to the operating room and the cast was removed. Not infrequently a small, inadequately debrided wound was found. Such wounds were opened widely, fascial planes were released, and the wounds were packed loosely with fine-meshed gauze. We questioned the extensive use of vaseline gauze, which, at times, actually plugged the wound.

The lower extremities were suspended in the half-ring splint, with skeletal traction through the tibial tubercle or the os calcis. Plaster was used more often for the upper extremity, unless it was feasible to use skeletal traction through the olecranon. Hot fomentations were applied locally, and penicillin therapy was begun. Transfusions were used, as indicated.

All femora which were in good position and not in danger of sepsis were left in plaster. The septic ones, or those with overriding, were placed in the half-ring splint, with skeletal traction through the tibial tubercle. Practically all were pulled into good alignment, if they were no older than three weeks. Essentially all patients whose fractures had kept good position during their evacuation to our Hospital were returned to the United States shortly after their reception, their wounds permitting, but only after a change of plaster. Patients with fractures, particularly of the femur, which required reduction in our Hospital, were kept there until there was sufficient consolidation to prevent displacement during transportation to the United States.

Based upon more than three years' experience in a General Hospital overseas, I have the following comments which may interest the surgeons who served in the forward areas. It is not intended to criticize the surgeons in the advance stations, whose work was, as a rule, of the highest order.

1. Adequate débridement was too often not done.

2. Wounds were at times too tightly packed with vaseline gauze; this was particularly true in the early days of the War and was not entirely unheard of as late as 1945.

3. Not infrequently we believed that bone was sacrificed unnecessarily at the original débridement. The orthopaedic surgeon in the Reconstruction Hospital will beg of you to preserve every particle of bone which has the slightest chance of survival, with the hope that it will bridge the gap between the main fragments and thus make the eventual grafting simpler.

4. Plasters applied in the forward areas were, on the whole, satisfactory. If there was adequate padding, there was no need to split the plaster casing prior to the evacuation to the rear.

5. Wire splints were not good for transportation.

Dr. W. H. McGaw, Cleveland, Ohio: From the Guadalcanal offensive to the completion of the initial campaigns in New Guinea—at Buna, Lae, and Finschaefen—our General Hospital, which happened to be the first to arrive in the Southwest Pacific, was left farther and farther in the rear of the fighting.

In those early campaigns, the wounded reached us from four to six weeks after injury. During that time, most of our patients were transported by hospital ship or overland in long Australian hospital trains. We frequently received from 300 to 500 patients in a convoy, and in one instance 700 patients were received in one day. Many of the patients who arrived by hospital train spent two or three nights

on the train. Medical officers from our General Hospital were always sent to meet these convoys about a day before their arrival. These officers then checked each patient's general condition and diagnosis. Patients were tagged for a particular service or ward before they left the train, and those in doubtful condition were earmarked for the first ambulances and for immediate surgical attention. Wounds were inspected, and casts were changed immediately, if necessary. Many of the patients received immediate transfusions of plasma or blood. All of the patients with compound fractures reached us in plaster casts, and, with the exception of those with fractures of the femur, most of them remained in plaster. Those with fractures of the femur were usually put in balanced skeletal traction until an adequate callus had formed. Then the patient's limb was immobilized in a plaster spica for the long trip home across the Pacific, which usually took from three to four weeks.

In some of the early cases, tight vaseline packing was found in the wounds; presumably this treatment was used for the control of hemorrhage. A general anaesthetic was occasionally needed in the removal of such packing. Rarely did a patient reach us without adequate débridement of the wound.

In the spring of 1944, our Hospital was moved from Melbourne, Australia, to Finschaefen, New Guinea. There we began receiving much more recent cases. A few of these were transported by air, reaching us within two to four days. Most of them, however, reached us by ship in from ten to fourteen days following the injury.

The general condition of the patients in New Guinea always received primary attention. It was the usual thing for a soldier to have lost from fifteen to twenty-five pounds even before he received his wound. Most of the patients with compound fractures showed signs of secondary anaemia and dehydration on arrival. As Colonel Eaton has mentioned, this condition of the patients facilitated reduction of the fracture, but definitely delayed its healing. Many of the patients arriving during this period had been evacuated from beach installations, and they had frequently been loaded and landed by water craft and by amphibious ducks of all kinds. They occasionally arrived with their casts softened by salt sea spray and even by vomitus. Maggots were found in some of the wounds. In addition, a great number of the patients had high fever, due to malaria or hepatitis. Large quantities of whole blood and plasma were sometimes needed over a long period of time. Practically all of the compound fractures were boarded to be sent to the Zone of the Interior as soon as transportation was available and as soon as the condition of the fracture and wound was suitable for a trip across the ocean of from three to four weeks, usually not in a hospital ship. The patients with fractured femora, naturally, had longer stays in our Hospital than any other group. Their average stay was about three months.

The wounds were occasionally closed secondarily, and an effort was made to cover any exposed bone at the earliest possible moment. This was sometimes possible with relaxing incisions; split-thickness grafts and pedicle skin grafts were occasionally used to cover large wounds before the patients were sent home.

The following table lists the types of compound fracture evacuated to the Zone of the Interior from our Hospital between April and September 1944. These patients were wounded during the Aitape, Hollandia, Biak, Noemfoor, and Sansapoor campaigns.

	Number	*Per Cent.*
Tibia and fibula	58	27
Femur	49	22
Humerus	37	17
Radius and ulna	27	12
All others (except spine and skull)	49	22
Total	220	100

Twenty per cent. of the patients in this group sustained more than one compound fracture; 15 per cent. had nerve involvement as well as the compound fracture. During this same period, only thirty-three simple fractures were boarded to the Zone of the Interior.

During these extensive campaigns in the Southwest Pacific area, our Orthopaedic Consultant, Colonel Eaton, devoted much of his time to improving the care of the wounded. He saw these patients in the portable, station, and evacuation hospitals, as well as in the rear general hospitals. During the active campaigns he was close to the firing, whenever possible, helping a team in one hospital and then another. Eventually, he would see many of the same patients at the rear hospitals. He was constantly returning with fresh suggestions and information for improvement in the care of patients. Dr. Eaton called this "leg work", when actually his was the important "head work" of constant progress.

MUSCLE TRANSPLANTATION FOR PARALYSIS OF THE RADIAL NERVE

BY CAPTAIN HAROLD ALTMAN AND CAPTAIN RAYMOND H. TROTT

Medical Corps, Army of the United States

In wartime a relatively large number of cases of paralysis of the radial nerve, which are usually associated with compound fractures of the lower two thirds of the humerus, are seen in Neurosurgical Centers. In cases where the nerve has been explored and found to be injured to such an extent that repair cannot be accomplished, tendon transfer at the wrist results in function of the hand and wrist which approaches the normal in approximately two or three months. The authors are presenting the early results observed when tendon transplantations have been performed for irreparable lesions of the radial or dorsal interosseous nerve, which have had the maximum benefits of neurosurgery. If a careful technique has been observed, a good result can be obtained in every case.

The authors have had the opportunity of carrying out these procedures on twenty-two patients * at McCloskey General Hospital. The technique of Billington, with the right-angle incision on the extensor surface of the lower end of the forearm, was employed in the earlier cases, and resulted in either a slough of the incision near the angle or considerable oedema of the fingers and dorsum of the hand. It was necessary to keep the patient in bed with the upper extremity elevated for three weeks in order to overcome the oedema. In addition, it was often technically difficult readily to identify and release the necessary tendons for transplantation without an undue amount of traumatic handling of the tissues.

The difficulties encountered by the authors were contrary to those recorded by many experienced and capable authorities doing this type of work, who advocate wide exposure. The authors found that, by making several minor changes in the usual accepted techniques, better results could be produced in a shorter time, with no postoperative oedema; and early ambulation was possible on approximately the second day after operation.

The early results of the procedures were so encouraging that they were performed in a few cases in addition to nerve repair. The advantage of the operation in this group is the speed with which the paralyzed hand is transformed into a useful member. The transplanted muscles act more efficiently than a splint in helping to maintain the dorsiflexed position of the wrist during the recovery of the nerve. The operation has also helped to dispense with many months of physiotherapy, and has permitted early discharge from the Hospital. The possibility of overdevelopment of the dorsiflexors in those cases in which the radial nerve regains its power has been kept in mind by the authors. Unfortunately, it has been impossible to do a follow-up study after a lapse of time sufficient to justify a positive statement.

TECHNIQUE

The upper extremity is elevated during the preparation of the skin. A sterile elastic bandage is utilized to "milk" the hand and forearm completely of venous blood. A tourniquet, similar to a blood-pressure cuff, is applied to the arm and the pressure is kept at 260 millimeters of mercury.

The tendon transplantations are performed proximal to the dorsal carpal ligament, which is not disturbed (Fig. 1, *A*). A two-inch transverse incision is made on the extensor surface of the distal portion of the forearm, approximately one-half to three-quarters of an inch proximal to the proximal border of the dorsal carpal ligament. The skin edges are undermined for a distance of approximately three-quarters of an inch. The underlying large veins are carefully avoided. A small self-retaining retractor is inserted. A two-inch

* An additional six patients have been operated upon and followed since this series was completed. The results confirm the conclusions already formulated.

longitudinal incision is made through the subcutaneous tissue and the deep fascia, parallel to the superficial veins, over the region of the extensor digitorum communis tendons. These tendons are isolated, along with that of the extensor indicis proprius, and are retracted to the ulnar side of the wound with rubber-dam retraction. The tendon of the extensor digiti quinti proprius is isolated and placed in the same rubber-dam retractor.

The tendons of the abductor pollicis longus and the extensor pollicis brevis are then isolated and brought into the operative field by slipping a curved Kelly clamp under them. A rubber-dam retractor isolates them at the radial side of the incision. Lister's radial tubercle is palpated and is a landmark for the nearby tendon of the extensor pollicis longus. This tendon is included with those of the extensor pollicis brevis and abductor pollicis longus in the rubber-dam retractor.

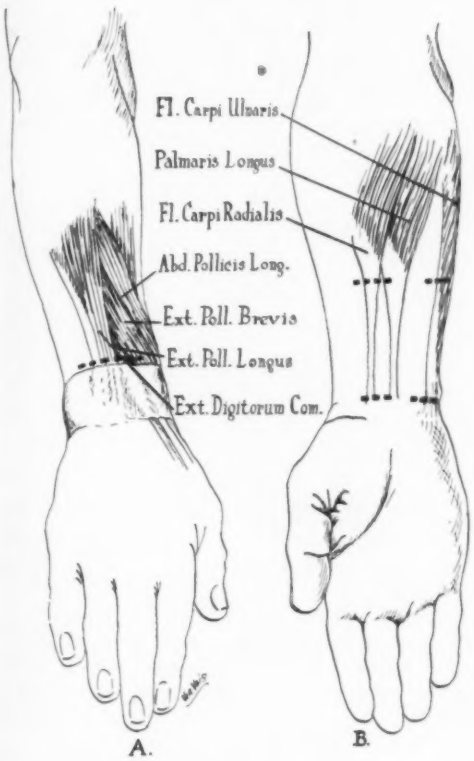

FIG. 1

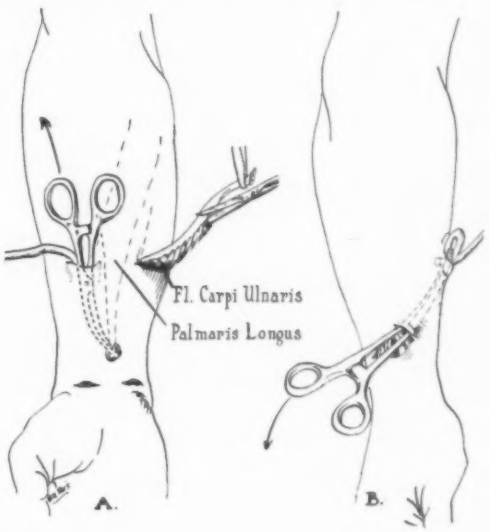

FIG. 2

Fig. 1: Demonstrates the incisions used in the operative procedure.

Fig. 2: *A*: The tendon of the flexor carpi radialis has been pulled free through the proximal incision. Clamp is on palmaris longus tendon, which is being carried to the same proximal incision. The flexor carpi ulnaris tendon has been retracted through its proximal incision and is being freed of its attached muscle fibers.

B: Flexor carpi radialis tendon is being carried through its subcutaneous tunnel to the extensor surface of the forearm. The palmaris longus tendon is lying free, awaiting its turn to be brought through the same tunnel.

The forearm is fully supinated and the tendons of the flexor carpi ulnaris and the flexor carpi radialis are identified by palpation, with the hand in cock-up position. It should be noted that the tendon of the flexor carpi ulnaris is on the radial side of the muscle, at the wrist. It is superficial to the volar carpal ligament, and is found approximately one-half inch from the ulnar border of the wrist. Although most surgeons have utilized an incision four or five inches long, so as to expose the entire course of these tendons, the authors have found it possible to free them through a small, half-inch transverse incision made in the skin over each tendon in the region of the distal transverse crease of the wrist (Fig. 1, *B*). The tendons are severed and are clasped with Kocher clamps. By exerting gentle traction on the proximal end of the severed flexor carpi ulnaris tendon, its location at the mid-forearm can be palpated. A half-inch transverse skin incision is made at this level. The Kocher clamp grasping the flexor carpi ulnaris tendon is then passed proximally

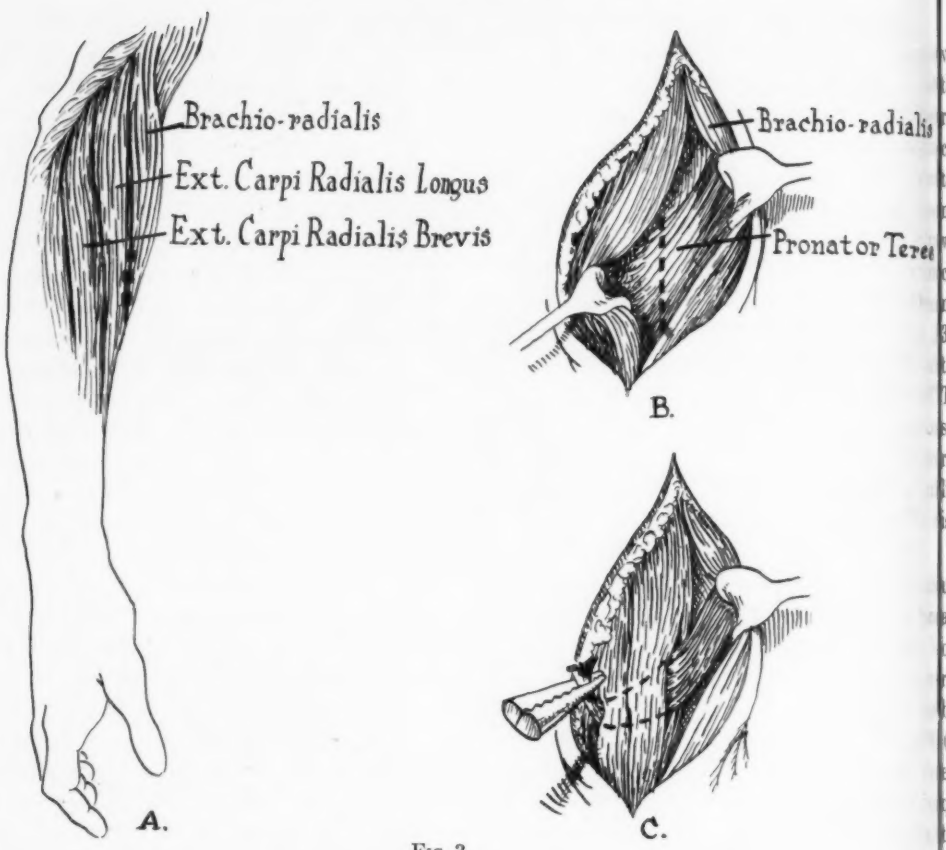

FIG. 3

A: Demonstrates approximate level of incision to isolate pronator teres tendon.

B: Brachioradialis is retracted to one side, extensor carpi radialis longus and extensor carpi radialis brevis to the other side. The underlying pronator teres tendon has been severed.

C: Tendon of pronator teres has been passed through musculotendinous portion of extensor carpi radialis longus and extensor carpi radialis brevis.

to the proximal transverse incision, and the tendon is extracted through it (Fig. 2, *A*). The muscle fibers on the flexor carpi ulnaris tendon are removed with a scissors, so that only the tendon remains. Some difficulty has been encountered in releasing this tendon, and this can probably be overcome by using tendon strippers of the proper gauge. A curved Kelly clamp is passed subcutaneously from the ulnar portion of the incision on the extensor surface of the forearm, proximally around the ulnar portion of the forearm, to the proximal incision on the flexor surface. The previously freed tendon is grasped and threaded through its subcutaneous tunnel. This should be deep to the large veins of the forearm.

The severed flexor carpi radialis tendon is passed proximally through a similar incision over the mid-portion of the flexor surface of the forearm, and then distally, subcutaneously, on to the radial portion of the extensor surface of the forearm (Fig. 2, *B*). The four small transverse incisions are closed.

The forearm is next placed in mid-position, and a longitudinal incision, one and one-half inches in length, is made over the site of insertion of the pronator teres tendon (Fig. 3, *A*). The brachioradialis muscle is retracted to one side; the tendons of the extensor carpi radialis longus and the extensor carpi radialis brevis are retracted to the other side The pronator teres tendon is severed along its radial insertion (Fig. 3, *B*).

The wrist and fingers are dorsiflexed, and the thumb is dorsiflexed and abducted by the assistant. This position must be maintained for the remainder of the operation and until a plaster splint has been applied.

A stab wound is made transversely through the substance of the tendons of the extensor carpi radialis longus and the extensor carpi radialis brevis. The pronator tendon is passed through these tunnels and sutured to each tendon with interrupted sutures of No. 0 chromic catgut (or silk) by the method described by Mayer (Fig. 3, *C*). The protruding portion of the transplanted tendon is excised. This is necessary to prevent adhesions being formed with the surrounding soft tissues, which will limit range of motion. Skin closure is effected.

The tendon of the flexor carpi ulnaris is similarly passed through and sutured to the extensor tendons of the index finger, middle finger, ring finger, and little finger, by the buttonhole technique of Mayer (Fig. 4, *B*). The holes in the recipient tendons are made with a mosquito clamp, which is pushed firmly through them at the desired levels. It was found that a No. 11 blade occasionally severed a small segment of one side of the buttonhole, if the operator was not unusually careful. The clamp method provides some additional safety, and was therefore adopted. The transferred tendon is passed through the newly made buttonholes, and is fixed to each paralyzed tendon by means of a small suture through both the proximal and distal ends of the buttonhole. That of the flexor carpi radialis is likewise passed through and sutured to the tendons of the thumb (the extensor pollicis longus and extensor pollicis brevis, and the abductor pollicis longus) (Fig. 4, *A*). The extensor pollicis longus tendon is divided one-fourth of an inch proximal to the muscle transfer. The fascia and subcutaneous tissue are closed with interrupted sutures of No. 0000 chromic catgut, which cover the recently transplanted tendons. The skin is closed.

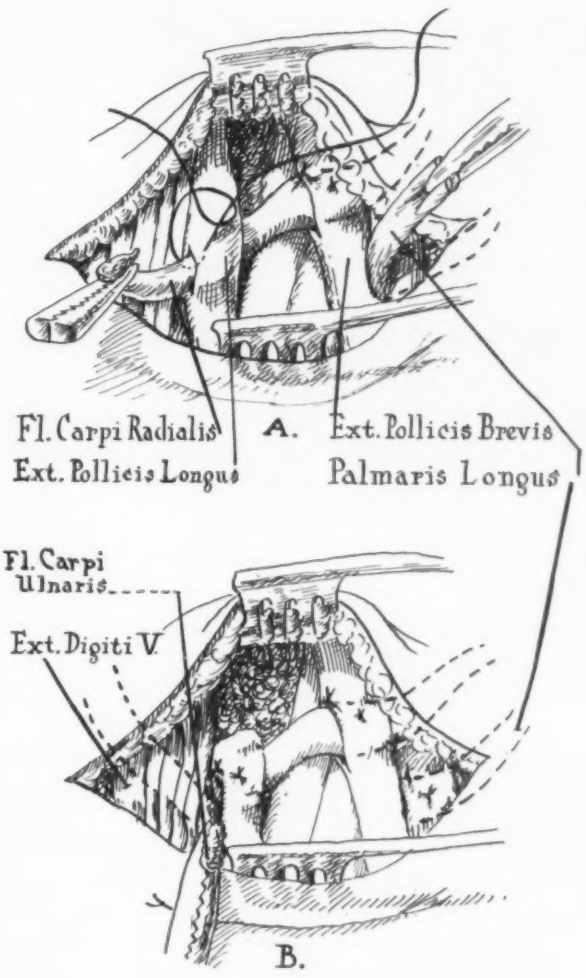

FIG. 4

A: Tendon of palmaris longus has been threaded through that of abductor pollicis longus. Flexor carpi radialis has been placed through tendons of extensor pollicis brevis and extensor pollicis longus.

B: Tendon of flexor carpi ulnaris has been brought through tendons of extensor digiti quinti proprius, extensor digitorum communis, and extensor indicis proprius.

In suturing the transplanted tendons into the donor tendons, the site of transfixion is chosen by pulling taut the paralyzed tendons and approximating the tendons to be transferred. Too much tension, however, is not desirable; it should approximate the physiological in degree. Sterile dressings are applied and are held in place with sterile sheet cotton. A plaster-of-Paris splint is then applied to the flexor surface of the extremity, maintaining the fingers in complete extension and the wrist in 30 degrees of cock-up position. The plaster extends from the proximal third of the forearm to the distal interpha-

langeal joints, and is held snugly in place with an elastic bandage. The tourniquet is then removed. No case of tourniquet paralysis has been encountered.

If the lesion is that of a dorsal interosseous nerve, the transplantation of the pronator teres tendon is not necessary.

After operation, the forearm is elevated by means of an irrigation stand for from one to two days. If no oedema is present, the patient is allowed to get up, with his upper extremity in a sling. From the time the patient has recovered from the anaesthesia, he is encouraged to move the ends of his fingers. At the beginning of the fourth week after operation the sutures are removed, and gradual active motion of the transplanted tendons is started. The patient is followed closely and is instructed in the proper use of the transplanted tendons, so that re-education is effected in a relatively short time. At the beginning of the fifth week, the plaster splint is worn only at night; it is discarded at the sixth week. The patient is started on some type of occupational therapy, requiring the use of his fingers and hands. Physical therapy should not be employed in these cases, since *active* use of the tendons is the best method of muscle re-education.

FIG. 5-A

FIG. 5-B

Demonstrate type of plaster-of-Paris splint used for postoperative convalescence.

SELECTION OF CASES AND RESULTS

Operation was performed upon those patients who had an irreparable injury, with loss of function of the radial or dorsal interosseous nerves. There had to be sufficient strength in the tendons to be transplanted so that they might act as motors.

In injuries of the dorsal interosseous nerve, the flexor carpi ulnaris and flexor carpi radialis were utilized rather than one of the extensor carpi radialis tendons, because both of the latter are necessary to stabilize the wrist in order to allow for good grip of the fingers.

Recently the palmaris longus tendon, where present, has been transplanted into the abductor pollicis longus tendon, rather than the flexor carpi radialis being used in all three thumb tendons. This, according to Bunnell, gives a better working thumb, although it is not entirely necessary. Various modifications of this procedure were used in instances of localized tendon paralysis, due to wounds of individual muscle bellies. War wounds provide varied bizarre types of injuries which are ordinarily not seen.

We have operated upon twenty-two cases, of which fourteen were injuries of the complete radial nerve and two were injuries of the dorsal interosseous nerve. Six were localized injuries of the extensor tendons. Good results were obtained in all cases. Each patient left

FIG. 6-A

FIG. 7

Two cases of complete radial-nerve injury, showing range of motion of fingers and wrist before operation.

FIG. 6-B

FIG. 8

Fig. 6-B: Same case as Fig. 6-A. Shows condition six weeks after operation.
Fig. 8: Another patient; excellent result three and one-half weeks after operation is demonstrated.

the Hospital with a functioning hand that had a strong, usable grip. Each case was reviewed by the Chief of the Orthopaedic Service and the Chief of the Neurosurgery Service, and was judged an excellent result. Dorsiflexion at the wrist was possible to 25 degrees above the straight line. Extension of all the fingers to completion was obtained at the interphalangeal joints. Complete extension at the metacarpophalangeal joints of the index finger, middle finger, ring finger, and little finger lacked approximately 15 degrees. At the thumb, however, complete extension and abduction were accomplished.

The earlier cases, in which the right-angle incision was used, were delayed in their recovery by sloughing at the angle or by oedema of the dorsum of the hand. With the modified technique, this has not occurred thus far.

NOTE: The helpful suggestions and cooperation of Lieutenant Colonel Harry C. Blair, Chief of the Orthopaedic Branch, have made this study possible.

REFERENCES

BILLINGTON, R. W.: Tendon Transplantation for Musculospiral (Radial) Nerve Injury. J. Bone and Joint Surg., **4**: 538–547, July 1922.

BUNNELL, STERLING: Surgery of the Hand. Philadelphia, J. B. Lippincott Co., 1944.

JONES, ROBERT: Tendon Transplantation in Cases of Musculospiral Injuries not Amenable to Suture. Am. J. Surg., **35**: 333–335, 1921.

MAYER, LEO: Tendons, Ganglia, Muscles, Fascia. *In* Lewis' Practice of Surgery, Vol. III, Chapter V. Hagerstown, Maryland, W. F. Prior Co., Inc., 1945.

BURSITIS IN THE REGION OF THE FIBULAR COLLATERAL LIGAMENT

BY I. E. HENDRYSON, M.D., DENVER, COLORADO

Voshell and Brantigan [1] have shown that bursitis in the region of the tibial collateral ligament is a distinct clinical entity. The author is not aware, however, of any report concerning a similar occurrence on the lateral aspect of the knee. In view of the frequency with which the lateral aspect of the knee is mentioned in connection with the diagnosis of "cyst of the lateral meniscus", the necessity for a description of bursitis in this region becomes apparent.

The purpose of this paper is to establish the identity of bursitis of the fibular collateral ligament as a definite clinical entity, to describe its pathology, and to consider its therapy.

HISTORY

The universal complaint associated with this bursitis is pain on the outer side of the knee. The pain is not characteristic, but descriptions of it range from "aching" and "burning" to "knifelike" and "stabbing" in quality. It is aggravated by exercise and, in most cases, is relieved by rest. In general, the duration of the discomfort is evaluated in terms of months rather than of days.

Causing almost as much concern to the patient has been the presence (in five of six cases) of a small swelling or "bunch", localized in the painful area on the outer side of the knee. The patient is not certain whether the mass appeared before or after the onset of pain, but he does know that the mass is slowly becoming larger and that it undergoes no remission.

It is difficult to assess the cause of his trouble, but the patient usually recalls a direct violence, a series of small injuries, or a repeated "banging" of the knee against some object, which, he feels, is of etiological significance. From a mechanical point of view, the knee bothers very little. Locking or blocking in the offending part is promptly denied. The patient may be aware of slight "insecurity", but no slipping has been noted.

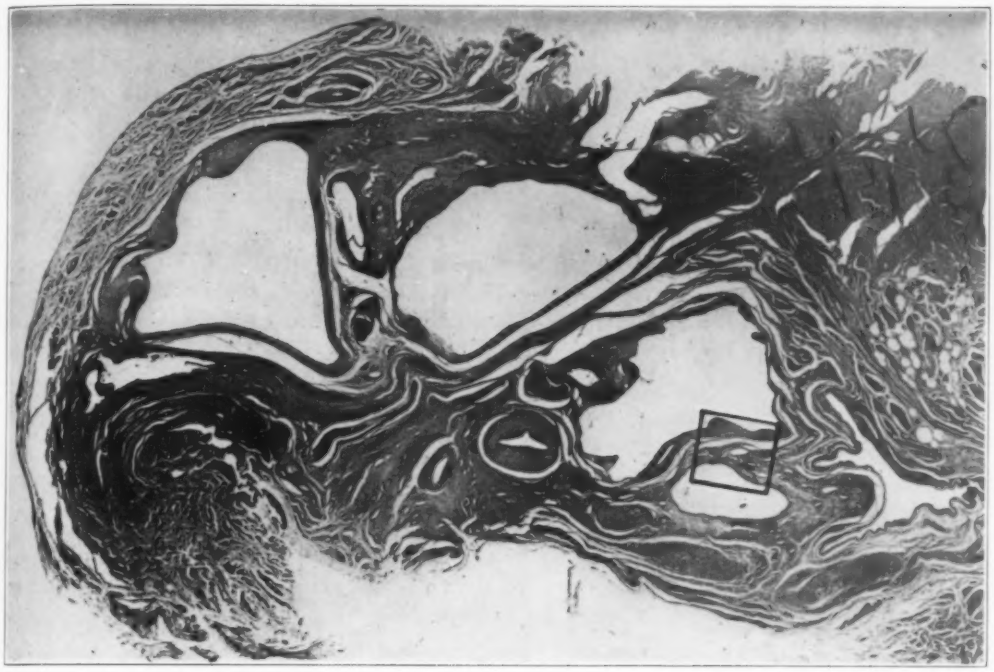

FIG. 1

Low-power view of section of bursal mass, which at operation was lying under and a little anterior to the fibular collateral ligament. Several bursae and the adjacent groundwork are shown clearly.

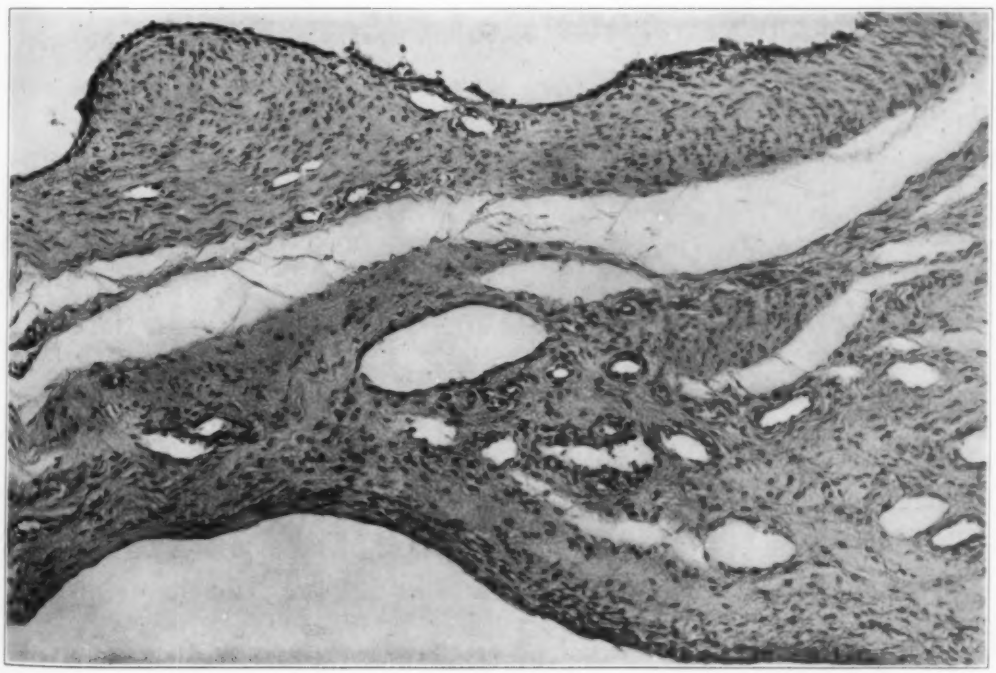

FIG. 2

High-power visualization of the area outlined in Fig. 1. Shows the structure of two of the larger bursae, and a small one in the center of the section.

TABLE I

CLINICAL DATA ON SIX CASES OF BURSITIS IN THE REGION OF THE FIBULAR COLLATERAL LIGAMENT

Patient	Knee	Symptoms and Signs	Duration of Symptoms	Etiology	Findings at Examination				Diagnosis		Findings at Operation	Recovery (*Days*)	Remarks
					Tenderness	Motion (*Degrees*)	Stability	Increase in Infrapatellar Circumference	Before Operation	After Operation			
S.C., white male, aged 36	Right	Pain, marked on full extension	3 to 4 months	Insidious	Over mass	180 to 40	5 degrees lateral instability	2 to 2.5 centimeters	Cyst	Bursitis	Mass, 1.5 by 2 centimeters, seen through rent in ligament, posteriorly	23	
H.B., male negro, aged 21	Right	Pain; mass increasing in size	10 years	Football injury; repeated lesser injuries	Over mass	180 to 35	Good	2.5 centimeters	Cyst	Bursitis	Mass, 1.5 by 3 centimeters, anterior to and under ligament	41	
H.S., white male, aged 32	Right	Dull pain, radiating down leg	2 years	Basketball injury, direct trauma	Over mass	180 to 40	Good	2 centimeters	Bursitis	Bursitis	Mass, 1.5 by 1.75 centimeters, anterior to and under ligament	21	
H.C., white male, aged 20	Right	Pain; mass getting larger	6 to 7 months	Volleyball injury; repeated twisting of knee	Over mass	180 to 45	Good	2 centimeters	Bursitis	Bursitis	Mass, 1 by 1.75 centimeters, under ligament	25	
D.S., white male, aged 24	Left	Mass on outer side of knee, aching, and pain	2 to 3 weeks	Using knee to open truck door	Over mass	180 to 35	Good	1.5 centimeters	Bursitis (determined by aspiration)	Bursitis		16	Recovery with aspiration and support
B.Q., white male, aged 31	Left	Pain and aching in knee	4 months	Knee twisted while walking over rough ground	Over ligament at joint line (no mass	180 to 35	Good	None		Bursitis		12	2% novocaine injection, 3 times, at 4-day intervals

PHYSICAL EXAMINATION

Examination reveals signs which are located entirely on the outer aspect of the knee, in the region of the fibular collateral ligament. Inspection may reveal a well-localized swelling at the joint line, varying from 0.5 to 3 centimeters in size. There is no evidence of intra-articular effusion. Upon palpation, the mass may be semi-fluctuant or firm in character; it is not freely movable, and is tender to pressure. Its location may be directly over the fibular collateral ligament, or in juxtaposition to one of its edges. The overlying skin may be tense, but it does not exhibit the signs characteristic of an inflammatory process.

Tenderness is specific, and is confined to a small area at the joint line, or just inferior to it. In the cases in which no mass is evident, the tenderness is elicited by pressure on the ligament as it crosses the areas mentioned. Adduction of the extended tibia on the femur produces the pain. Internal rotation of the flexed limb will also produce the pain in most cases.

Stability and motion of the knee are usually not involved. Full extension may be voluntarily resisted, however, due to pain caused by pressure of the ligament on the bursal mass. One patient has been seen in whom the mass was large enough to affect the integrity of the ligament, causing 5 degrees of lateral instability.

DIAGNOSIS

Without surgery, it may be impossible to prove the diagnosis conclusively. With the characteristic history, signs localized in the area of the fibular collateral ligament, and pain upon adduction of the tibia, however, such a diagnosis is warranted. When aspiration of the fluid in the mass is possible, radiopaque material may be injected, so that the bursa will be visualized upon roentgenographic examination.

PATHOLOGICAL FINDINGS

Gross Appearance

The semifluctuant swelling may lie directly under the fibular collateral ligament, or it may project anteriorly or posteriorly to it. When seen in the central position, the fibers of the ligament are taut and show thinning. The mass lies outside the synovial membrane, has no intimate connection with the meniscus, and is encapsulated by its surrounding areolar elements. Upon removal, it feels rubbery to touch, as though it had fluid at its center. It is cut with about the same ease as dense fibrous tissue, and permits the escape of small amounts of clear, yellow, viscous fluid. The central portion consists of several sacs of various sizes, surrounded by considerable fibrous tissue, which gives the whole a multilocular appearance.

Microscopic Appearance

The striking feature is the presence of several punched-out areas, irregular in shape, variable in size, and containing no visible exudate. In the main, these areas are lined by a layer of flat irregular cells, characteristically bursal in nature; but in some cases they become multicellular, with pyknotic and ovoid nuclei.

The groundwork and the tissue adjacent to the bursae are composed primarily of fibroblasts, densely laid down, and orderly in appearance. A few scattered round cells are noted in this fibrous tissue and, rarely, a neutrophil is seen. There is an increase in the smaller vascular elements throughout.

In sections which contain, in addition, the lateral meniscus, there is no evidence of change in the inherent fibrocartilaginous structure, nor evidence of association of that structure in the pathological process described.

TREATMENT

Management of this condition is fundamentally the same as that of bursitis in other locations. Those patients revealing no mass respond favorably to injection with novocain, support, and rest.

It is felt, however, that, in the majority of patients seeking treatment, some enlargement is present which requires attention. Aspiration of fluid from the mass is not uniformly successful. When it can be accomplished, subsequent rest and support of the knee are indicated; this often results in arrest of the condition.

The tendency for the pathological changes to involve more than one bursa leads to the conclusion that surgical removal of the entire mass is the treatment of choice. This procedure is not difficult, and requires only that protection of the fibular collateral ligament be assured. In those cases in which the mass underlies the central fibers of the ligament, adequate exposure is secured by making an incision longitudinal and parallel to them. Anterior or posterior enlargements may be approached by retraction of the ligament.

After operation, support is maintained (by means of sheet wadding and elastic-bandage dressing) throughout the period necessary for complete healing of the soft tissues. Early weight-bearing is permitted, and active motion is desirable only to the extent that it produces no undue pain. Quadriceps-setting exercises are instituted on the first day after operation, but other physiotherapy is not employed.

DISCUSSION

Although the pathological findings have been concerned wholly with cases in which a mass is present, it is reasonable to assume, from our general knowledge of the bursitides, that the condition exists and can produce symptoms without evidence of a visible or palpable enlargement. Such a case has been included in Table I, but the diagnosis has not been definitely proved by microscopic examination.

Although one bursa may be responsible for the gross appearance of the mass, it is evident microscopically that others of smaller size are involved in the same process. More often, multiple bursae are equally affected, giving rise to a multilocular enlargement. This fact explains the difficulty encountered in attempts at aspiration, and also points to the possibility of future recurrence.

The similarity of the condition to cystic degeneration of the meniscus emphasizes the need for care in dissecting out the mass at the time of operation. In bursitis, no involvement of the cartilage is observed and meniscectomy is unnecessary. It is evident that cartilages have been sacrificed which were free from any pathological condition other than that of lying adjacent to a bursa in the region of the fibular collateral ligament.

1. Voshell, A. F., and Brantigan, O. C.: Bursitis in the Region of the Tibial Collateral Ligament. J. Bone and Joint Surg., **26**: 793–798, Oct. 1944.

AIR ARTHROGRAPHY AS AN AID TO DIAGNOSIS OF LESIONS OF THE MENISCI OF THE KNEE JOINT

BY SQUADRON LEADER E. W. SOMERVILLE
Royal Air Force Volunteer Reserve

Since the outset of World War II, many men have exchanged their comparatively sedentary ways of civilian life for the more energetic life in the Services, with the result that the number of minor injuries has increased considerably. The knee joint is one of the regions most frequently affected, and injuries vary from simple sprains to the more extensive lesions in which the structures of the joint are torn or fractured.

Sometimes the clinical differentiation of these lesions is difficult. Thus in some cases, the correct diagnosis cannot be made until arthrotomy has been performed. For this reason, attempts have been made in the past to devise methods to aid or to reinforce the clinical examination.

Foremost among these methods has been the use of roentgenograms. First a contrast medium is injected, which may be either positive or negative, and which outlines the soft structures of the joint. Various media, such as oxygen, air, and uroselectan, have been used, and many different positions for taking effective roentgenograms have been advocated by Kleinberg, Quaintance, Cullen and Chance, Hauch, and Somerville.

A technique of outlining the menisci, without injection of a contrast medium, has been described by Dittmar, by Rubin, and by Evans. This method depends upon the phenomenon that, when the articular surfaces of a joint are forcibly separated, a thin line of translucency appears, which outlines the true joint space. If the separation of the articular surfaces is maintained, the translucency lasts for as long as ten minutes. Any fluid in the joint makes this translucency impossible. It is believed that the translucency is due to the extraction of gases from the tissues, as a result of the negative pressure. In the case of the knee joint, the separation of the articular surfaces can be obtained by forcibly adducting or abducting the tibia on the femur.

In the present series, 331 knees have been examined by air arthrography. The technique employed combines the more important features described by previous workers. While the basis of the technique has remained the same in all cases, many variations in detail have been tried and improvements have been made from time to time.

TECHNIQUE

In the earlier cases in the series, air arthrography was done separately from the clinical examination and the examination under anaesthesia. In subsequent cases, the following routine was found to be more satisfactory:

After a skin preparation of forty-eight hours, the patient is taken to the operating theater, where the clinical examination is repeated and the straight roentgenograms are reviewed. Pentothal-sodium anaesthesia is used; the knee is examined; and any abnormalities are noted. The towels used in preparation are removed, and the skin is cleaned with alcohol. The knee is then filled with air, which is injected through a needle of medium bore, inserted in the outer side of the joint at a level with the lower pole of the patella. Prior to injection, the air is filtered through cotton wool; a twenty-cubic-centimeter syringe with a two-way cock is used (Fig. 1).

After the needle has been removed, the puncture wound is sealed with mastisol, and a dressing is applied. Towels are reapplied and are fixed securely so that they will not slip with subsequent manipulation. Should a lesion be found, the patient will be ready for operation on the following day. He is then transferred to the X-ray Department.

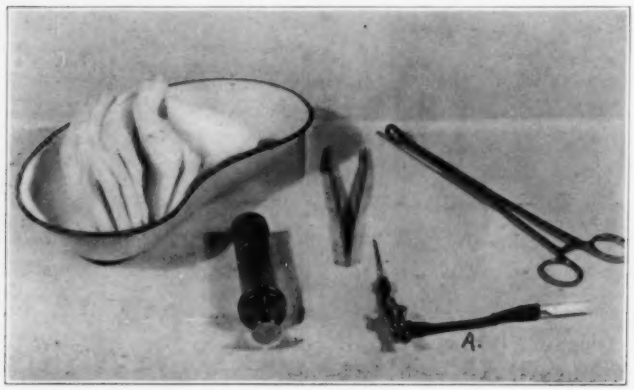

FIG. 1

Instruments used for injection of air into knee joint. *A*: Two-way cock and filter of cotton wool.

FIG. 2

Curved stand, showing cassette in position.

Roentgenography

The apparatus employed in taking the roentgenograms consists of a stand, six inches high, with a curved top, into which a curved cassette, eight inches by ten inches, can be inserted (Fig. 2). A sinus cone, sixteen inches in length by two and one-half inches in diameter, is used; the distance from tube to film is approximately twenty-four inches. Fifty-five milliamperes, forty-five kilovolts, and 0.4 second of exposure are given.

A crepe bandage is applied firmly above the knee in order to express the air from the suprapatellar pouch and to raise the intrajoint pressure temporarily. By this technique, a smaller quantity of air can be used, with greater advantage.

Certain routine views are taken first in all cases, and later other views are taken which may be suitable in a particular case. The routine views have been labeled M.1,

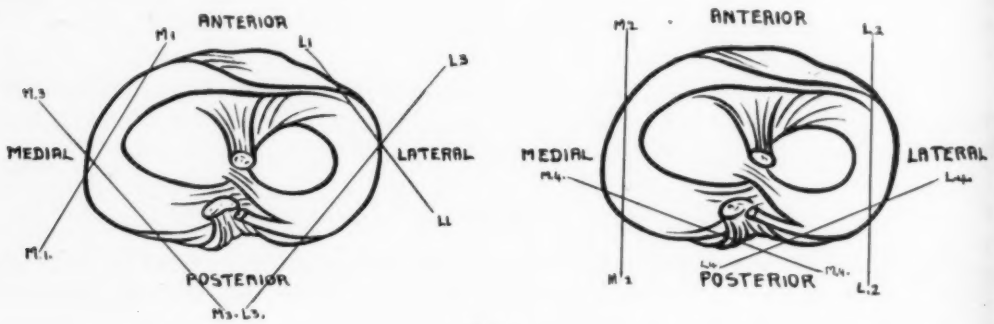

FIG. 3

The four routine views of each meniscus.

M.2, M.3, M.4 (medial) and L.1, L.2, L.3, L.4 (lateral); they are tangential views of the menisci (Fig. 3). Anteroposterior and lateral roentgenograms of the whole joint are also taken; and, in certain cases, axial views of the patella.

Views 1 to 3, medial and lateral, are taken with the knee slightly flexed over the curved stand at an angle of approximately 150 degrees. The cone and tube are adjusted so that the central ray is focused on the center of the stand at the level of the knee joint, with the cone at an angle of 80 degrees to the horizontal. The operator extends the patient's knee slightly until the tibia and the cone are at right angles to each other, at which time the central ray should pass through the side of the joint being examined. By

FIG. 4

FIG. 5

Fig. 4: Shows position and technique for taking routine views. Note crepe bandage firmly applied above knee. View M.2 is being taken. The tibia is being abducted on the femur during the exposure, thus widening the inner side of the joint.

Fig. 5: Technique employed in taking Views M.4 and L.4. M.4 is being taken. The knee is flexed to 90 degrees, while the thigh is steadied with one hand and the tibia is internally rotated with the other hand.

this means, all the views may be taken by simply moving the knee and rotating it to whichever side is necessary, with no further adjustment to the cone or the stand except for the insertion of fresh cassettes. Two views can be obtained on each film; if three cassettes are used, the entire examination can be completed in about two minutes.

The position of the joint is localized by palpation; with practice, this method has proved sufficiently accurate. The use of a fluorescent screen to outline the joint exactly is time-consuming and unnecessary.

While each view is being taken, the tibia is either abducted or adducted forcibly on the femur, in order to widen the side of the joint being examined (Fig. 4).

FIG. 6

Technique employed in taking "skyline" view of the patella.

If the knee is in full extension and the lateral ligaments are intact, it is impossible to widen either side of the joint; but, if the knee is slightly flexed, the lateral ligaments are relaxed, and even in the tightest joint a certain amount of widening can be obtained. This procedure proved satisfactory in Views 1 to 3 (medial and lateral). Occasionally, however, a lesion in the posterior part of the meniscus will not be seen by this method, but may be demonstrated by a different technique.

For this purpose, the patient is turned on his side and the knee is flexed to an angle of 90 degrees with a flat cassette, six inches by eight inches, beneath it. The cone is brought down to the knee and is focused so that the central ray will pass through the back of the joint. The tibia is rotated medially or laterally on the femur (Fig. 5), so that either the medial or the lateral tibial condyle will be posterior, and will therefore be outlined clearly, with the respective meniscus on the posterosuperior aspect.

Since the conclusion of this series, a technique has been devised for outlining the articular cartilage of the patella and the adjacent articular cartilage of the femoral condyles. The knee is filled with considerably more air than is used for the other views. The compression bandage is applied above the knee, and the knee is flexed over the curved stand to the greatest extent possible without obliterating the patellar tap. With an

ordinary dental occlusal film pressed hard into the patellar ligament, immediately above the tibial tuberosity, a roentgenogram is taken, as shown in Figure 6.

INTERPRETATION OF ROENTGENOGRAMS

Upon examination of a straight roentgenogram of a knee containing air, the following soft-tissue structures may be seen: both menisci, the cruciate ligaments, the articular cartilage, and a retropatellar pad of fat. There is a clear outline of the joint itself and of the communicating bursae. The bony detail also appears better defined than is usually seen in roentgenograms of joints not containing air. Unfortunately, many of these shadows overlap and produce a misleading appearance. On the outer side of the joint, the shadows are further complicated by the presence of the tendon of popliteus, which separates the lateral meniscus from the fibular collateral ligament. The synovial sheath of this tendon is filled with air. The number of misleading shadows is considerably reduced—though, unfortunately, not completely excluded—by the technique previously described of widening the joint on one side.

Normal Appearance of Menisci

The normal appearance of the menisci is shown in Figures 7 and 8. These diagrams show the average shape and relative size of both menisci, but considerable variation may be seen without a significant abnormality being present. In each view, the meniscus is seen in cross section.

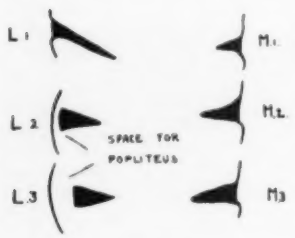

FIG. 7

Diagrammatic representation of six routine views of the menisci, as seen by air arthrography. Each view is taken separately.

Medial Meniscus: The medial meniscus is firmly adherent to the capsule and to the tibial collateral ligament peripherally in its whole length. In View M.1, the meniscus is small and triangular in shape and it does not

FIG. 8

Diagrammatic representation of View M.4. The meniscus can be seen, lying on the posterior lip of the medial tibial condyle.

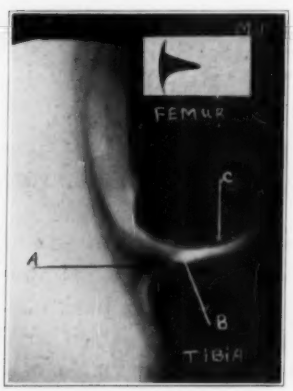

FIG. 9

FIG. 10

FIG. 11

Fig. 9: View M.1, showing a normal medial meniscus at its anterior end. *A*, Meniscus; *B*, air in joint; *C*, femoral articular cartilage. Inset shows average size and shape of meniscus.

Fig. 10: View M.2, showing normal medial meniscus at its mid-point. *A*, Medial meniscus. Inset shows differently shaped meniscus which is often seen.

Fig. 11: View M.3, showing normal medial meniscus in its posterior portion. *A*, Medial meniscus, which is a little longer than usual. Inset shows more usual size.

protrude far into the joint. As examination continues posteriorly, the triangular shape of the meniscus is maintained, but its size is increased considerably in Views M.2 and M.3 (Figs. 9, 10, and 11), and it can be seen protruding farther between the articular surfaces.

In M.4, the meniscus can be seen lying on the posterosuperior aspect of the tibial condyle, with its peripheral attachment sweeping away posteriorly to form a pouch filled with air (Fig. 12). In a normal knee, there is no break in the smooth line. A second pouch filled with air may sometimes be seen beneath the peripheral attachment of the meniscus, lying between it and the

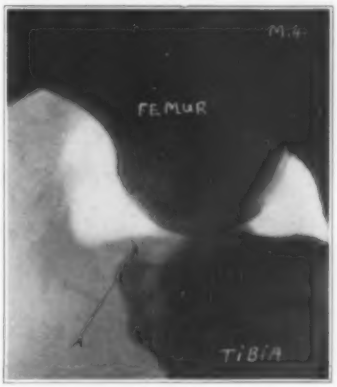

FIG. 12

Fig. 12: View M.4, showing normal medial meniscus (*A*), lying on posterior lip of medial tibial condyle.

FIG. 13

FIG. 14

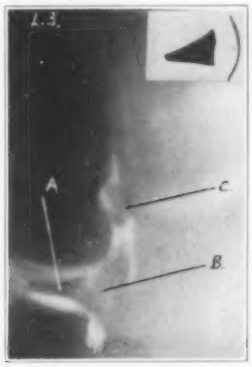

FIG. 15

Fig. 13: View L.1, showing normal lateral meniscus in its anterior portion (*A*). Inset shows normal shape and size of meniscus.

Fig. 14: View L.2, showing normal lateral meniscus at mid-point. *A*, Meniscus; *B*, small separation produced by tendon of popliteus. Inset shows normal arrangement.

Fig. 15: View L.3, showing normal lateral meniscus in posterior portion. *A*, Meniscus; *B*, normal separation; *C*, sesamoid bone in gastrocnemius.

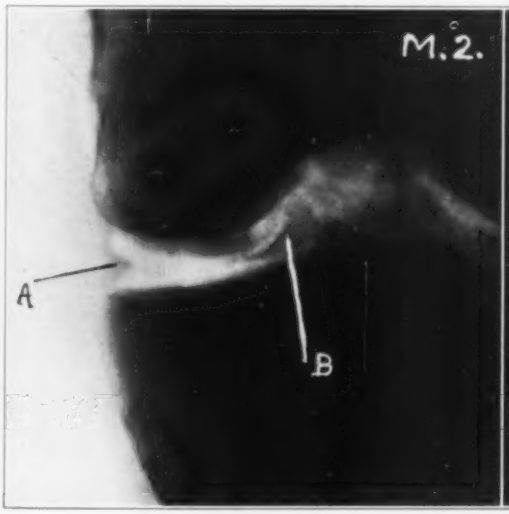

FIG. 16-A

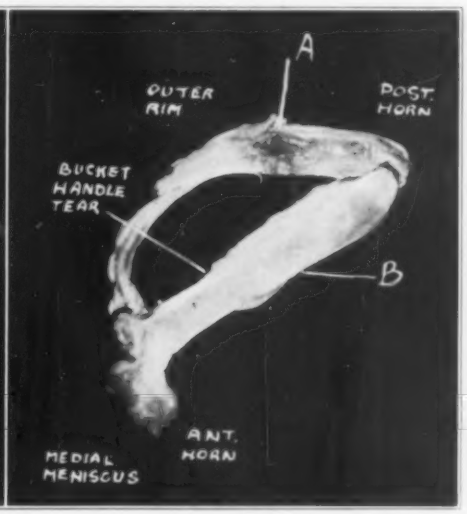

FIG. 16-B

Fig. 16-A: Arthrogram showing bucket-handle lesion of medial meniscus. *A*, Outer rim; *B*, displaced bucket handle. Fig. 16-B: Shows meniscus subsequently excised.

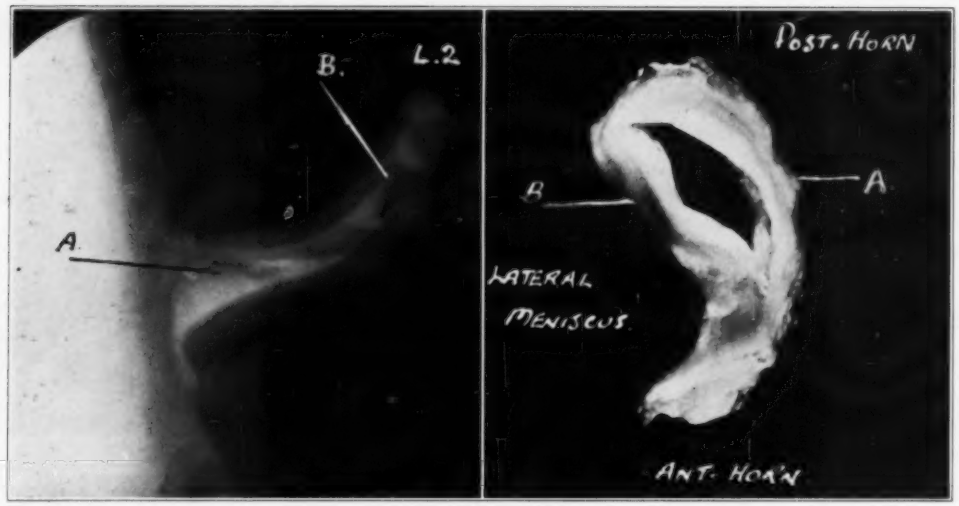

FIG. 17-A FIG. 17-B

Fig. 17-A: Arthrogram showing bucket-handle tear of lateral meniscus. *A*, Outer rim; *B*, displaced bucket handle.

Fig. 17-B: Shows meniscus after excision.

tibia (Fig. 29). This is usually small in size; but, if it is large, it may indicate a loosely attached meniscus. These appearances suggest strongly that, when the normal knee is in a position of flexion, there is a tendency for the meniscus to be drawn out of the back of the joint.

Lateral Meniscus: The lateral meniscus is entirely different from the medial meniscus in shape and size. Anteriorly, in L.1 it is long and thin, extending from the capsule, with which it is continuous, well into the joint, and it is raised from the tibia (Fig. 13). As the examination continues posteriorly, it becomes more triangular in shape. In L.2 it may be

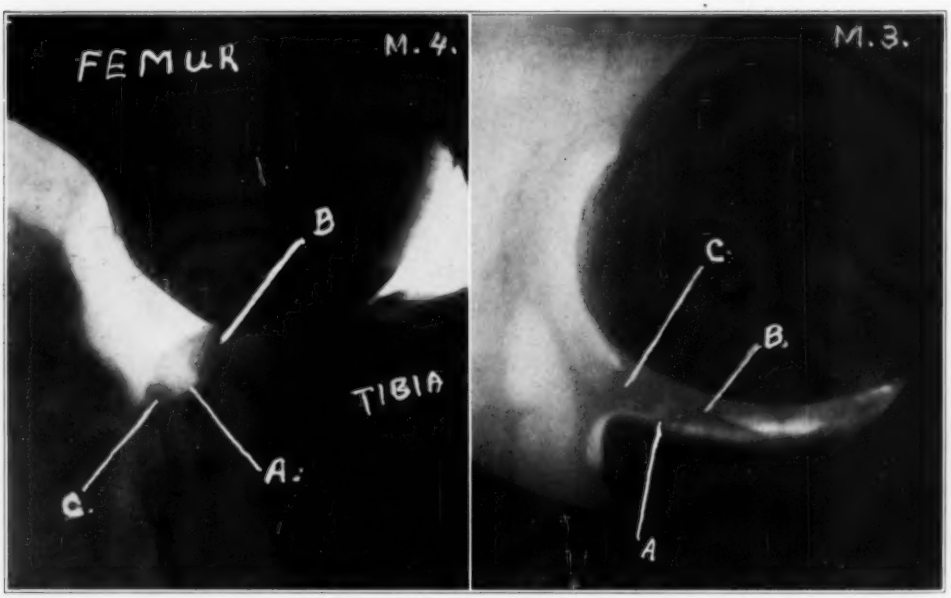

FIG. 18-A FIG. 18-B

Tear of posterior horn of medial meniscus, as shown in Views M.4 and M.3. *A*, Tear of posterior horn; *B*, displaced portion of meniscus; *C*, peripheral rim.

either continuous with the capsule, or, as is more frequently the case, slightly separated from it by the tendon of popliteus (Fig. 14). In L.3 it is always separated peripherally from the capsule by a wide gap, which again is produced by the tendon of popliteus. This peripheral separation should not be mistaken for a tear. It is always present, but is usually not wider than three-eighths of an inch. Its presence makes the interpretation of lesions of the lateral meniscus more difficult than those of the medial meniscus (Fig. 15).

View L.4 is not very satisfactory, and present experience indicates that it would be unwise to place much reliance upon it. The appearance is similar to that seen in M.4, but it is not so clear and the posterior part of the separation produced by the tendon of popliteus may be very misleading.

FIG. 18-C
Shows the meniscus itself.

Lesions of Menisci

It is usually possible to make a definite diagnosis from an arthrogram as to what type of tear is present in a meniscus, but in certain cases it is only possible to say that a lesion is present. This is particularly true of the lateral meniscus.

Bucket-Handle Tears: These lesions can be diagnosed with considerable accuracy, both in the medial and lateral menisci, particularly if the bucket-handle portion is displaced into the intercondylar notch. If, however, the displaced portion is very small, as is occasionally the case, it may not be possible to differentiate it from the shadows of the cruciate ligaments in the intercondylar notch. It is safer, therefore, to diagnose this lesion by the presence of a small, irregular outer rim, and to ignore the shadows in the center of the joint. If the bucket handle is not displaced, a definite split can be seen in the cartilage substance itself (Figs. 16-A, 16-B, 17-A, and 17-B).

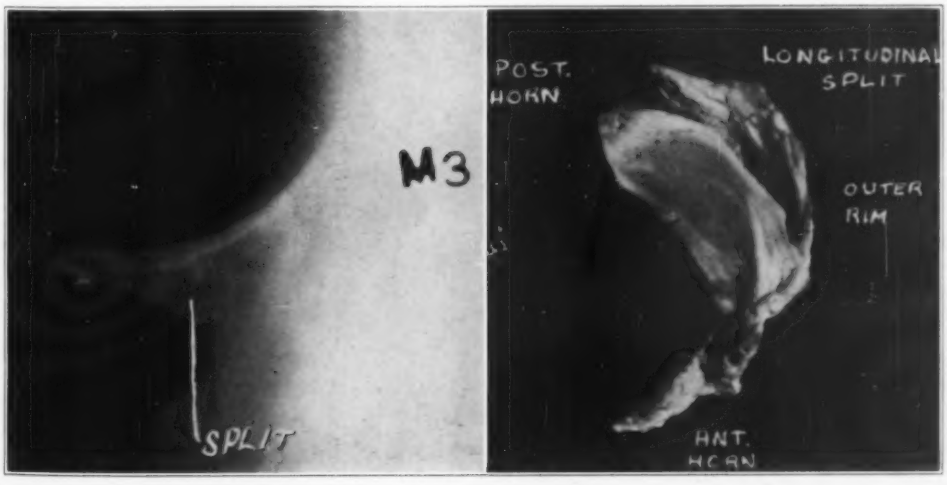

FIG. 19-A FIG. 19-B

Fig. 19-A: Arthrogram showing irregular tear of posterior horn of medial meniscus, as seen in View M.3.

Fig. 19-B: Excised meniscus.

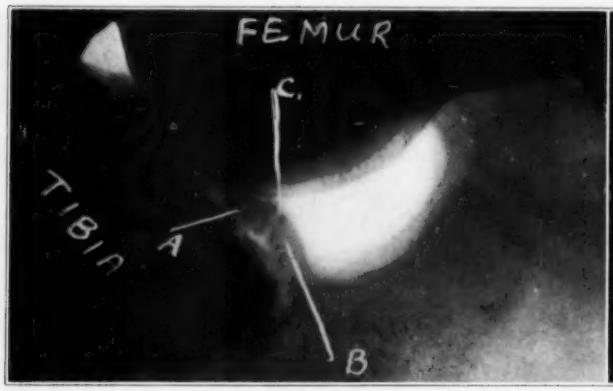

FIG. 20-A

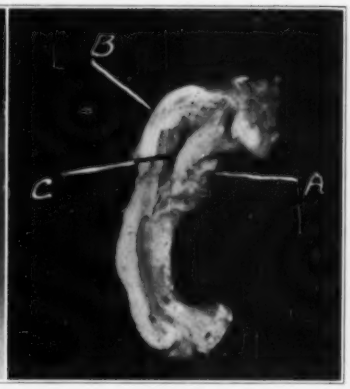

FIG. 20-B

FIG. 21-A

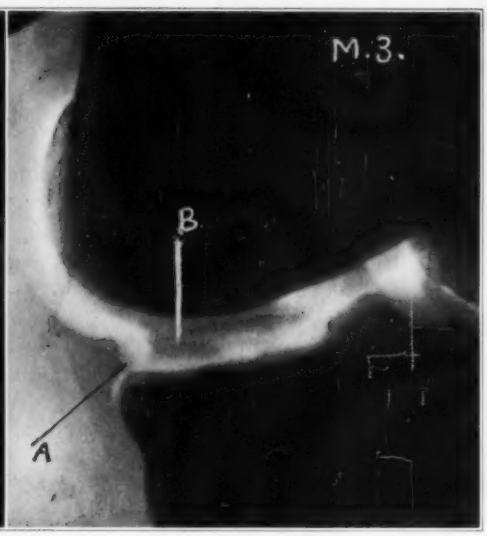

FIG. 21-B

FIG. 21-C

Fig. 20-A: Tear of posterior horn; seen in View M.4, but not in other views.

Fig. 20-B: Excised meniscus. *A*, Displaced portion of meniscus; *B*, peripheral rim; *C*, small tear.

Figs. 21-A and 21-B: Peripheral tear of medial meniscus, as seen in Views M.2 and M.3. *A*, Peripheral tear. No outer rim seen in M.2, but faint rim is seen in M.3. *B*, Displaced portion of meniscus.

Fig. 21-C: Excised meniscus.

FIG. 22-A

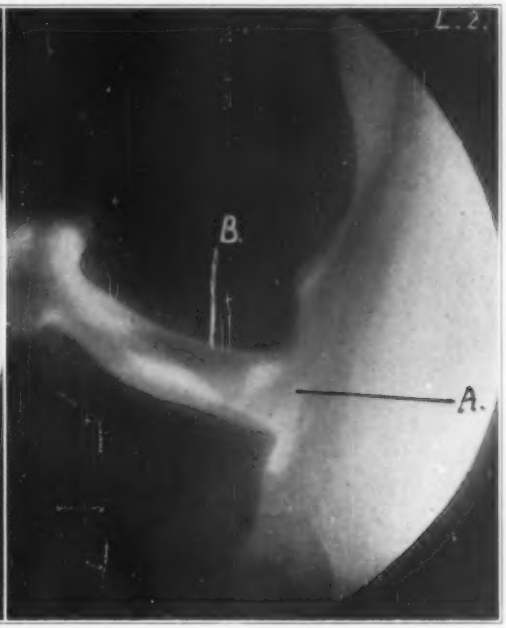

FIG. 22-B

Figs. 22-A and 22-B: Peripheral tear of lateral meniscus, as seen in Views L.1 and L.2, resulting in widening and lengthening of the normal separation, due to tendon of popliteus. *A*, Separation; *B*, meniscus.

Fig. 22-C: Excised meniscus.

Fig. 23-A: Arthrogram in View M.3, showing tear near the periphery of a medial meniscus.

Fig. 23-B: Excised meniscus.

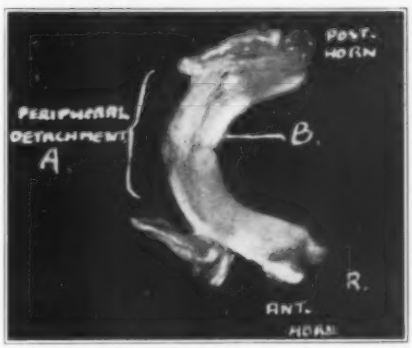

FIG. 22-C

FIG. 23-A

FIG. 23-B

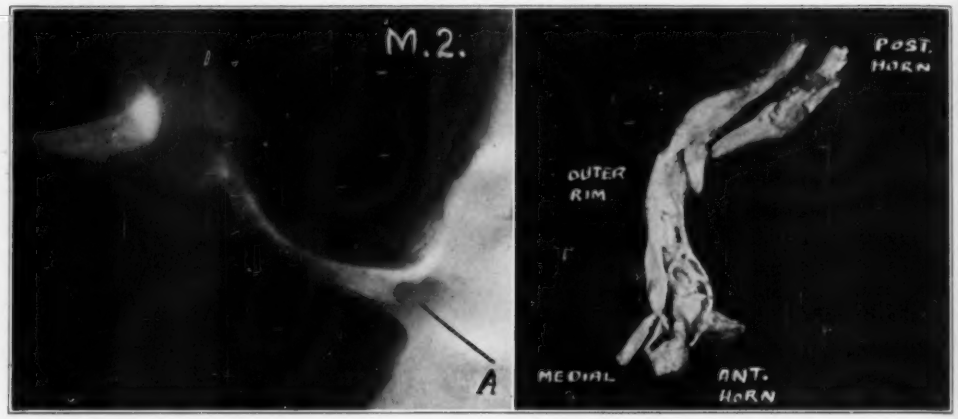

FIG. 24-A FIG. 24-B

Fig. 24-A: Arthrogram in View M.2 shows severely contused meniscus. *A*, Contused meniscus.

Fig. 24-B: Excised meniscus. The apparent splits in the meniscus are due to the fact that it was removed in several pieces, through two incisions.

Lesions of the Anterior and Posterior Horns: Lesions of the posterior horn are seen in Views M.3 and L.3, and may also be seen in M.4; View L.4 is unreliable. When the lesion is in the medial meniscus, an obvious split can be seen, which may appear to be either in the meniscus itself or at its peripheral attachment. In M.4, the lesion is seen on the posterior lip of the tibial condyle.

Peripheral tears of the lateral meniscus consist of enlargement, either forward or backward, of the separation which is normally produced by the tendon of popliteus. This permits undue mobility of the meniscus, which can be seen displaced toward the center of the joint, lying between the condyles of the femur and the tibia. This results in widening of the normal peripheral separation. If this separation appears to be wider than one-half inch, a lesion is probably present (Figs. 22-A and 22-B).

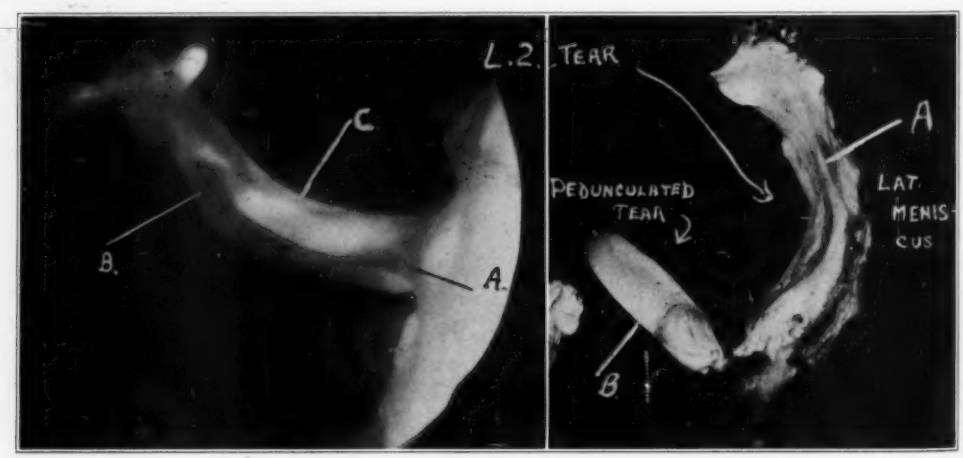

FIG. 25-A FIG. 25-B

Arthrogram, in View L.2, shows severely contused lateral meniscus, with large anterior tag. *A*, Contused rim of meniscus, containing small but definite split; *B*, large anterior tag displaced and lying in intercondylar notch; *C*, definite area of erosion and thinning of articular cartilage of femur, subsequently confirmed at arthrotomy.

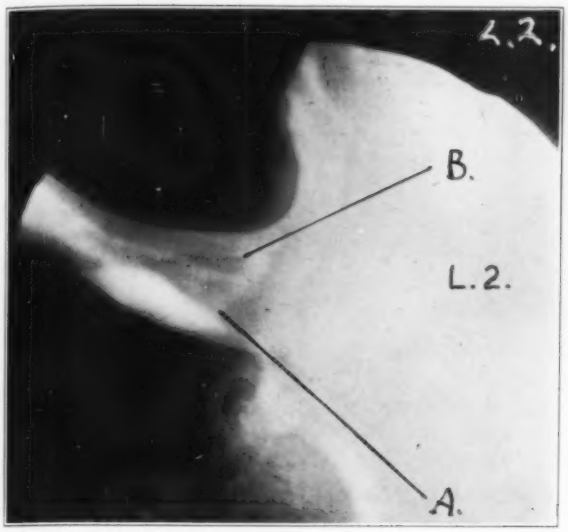

FIG. 26-A

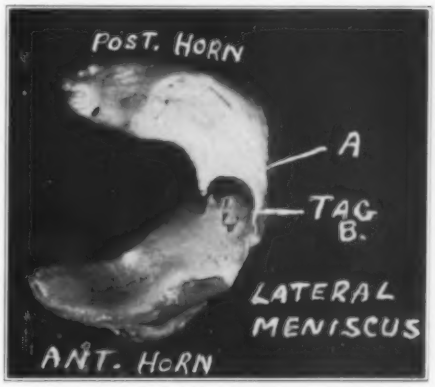

FIG. 26-B

Fig. 26-A: Arthrogram in View L.2, showing a horizontal tear of the lateral meniscus. *A*, Main part of meniscus; *B*, tag on upper surface. The tear can be seen between *A* and *B*.

Fig. 26-B: Excised meniscus.

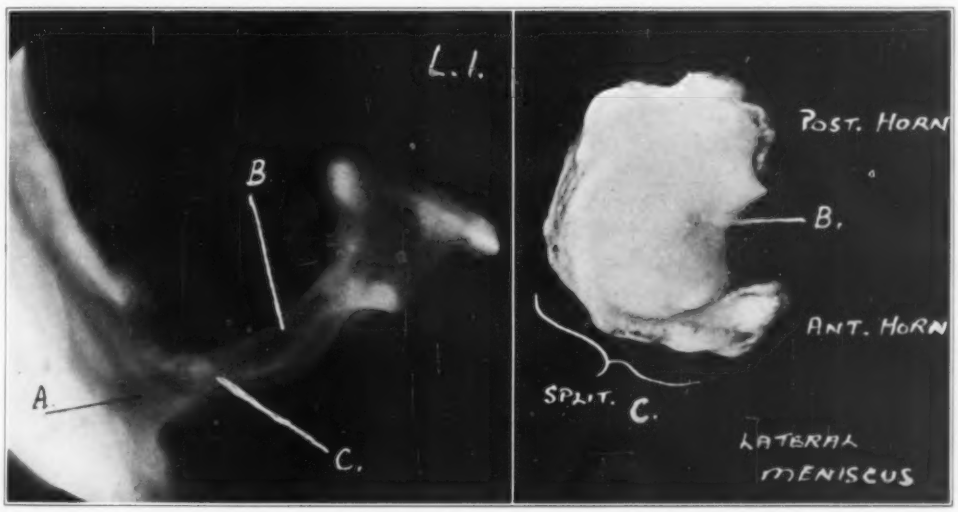

FIG. 27-A FIG. 27-B

Fig. 27-A: Arthrogram in View L.1, showing tear at periphery of lateral discoid meniscus. *A*, Peripheral attachment; *B*, main body of meniscus; *C*, peripheral tear.

Fig. 27-B: Excised meniscus.

Miscellaneous Lesions: Other types of lesions of the menisci should be considered.

1. *Persistent Remnants of Posterior Horn*: Pieces of menisci of various sizes may be seen, usually in the views of the posterior horn, following incomplete meniscectomy. The size of the remnant is always exaggerated on the arthrogram.

2. *Contused Menisci* (Figs. 24-A and 24-B): This type of damaged meniscus has perhaps not received sufficient recognition. The clinical picture is often rather indefinite. Locking and giving way of the knee are unusual. In the arthrogram, the outline of the meniscus is rounded and irregular and appears to be smaller than usual. The appearance often suggests that a bucket-handle lesion may be present, with the displaced bucket handle concealed by the shadows in the intercondylar notch.

3. *Tag Lesions*: Pedunculated tags result from old longitudinal or oblique tears, in

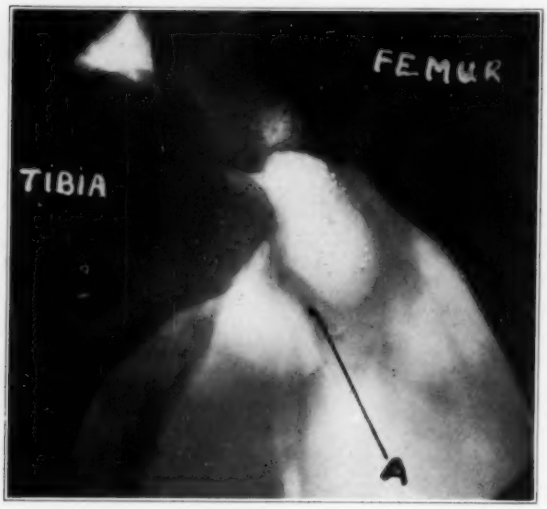

FIG. 28

FIG. 29

Fig. 28: Arthrogram in View M.4, showing "hypermobile" medial meniscus. *A*, The long lax synovial attachment of the meniscus.

Fig. 29: Arthrogram showing lesser degree of hypermobility of medial meniscus, as seen in View M.4. *A*, The medial meniscus is drawn out of back of joint more than is customary. A pouch can be seen above and below it. Arthrotomy was not performed in this case.

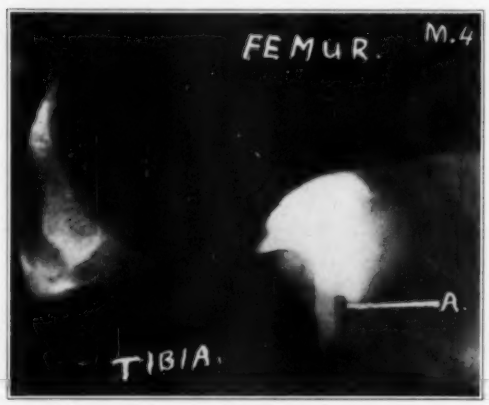

FIG. 30

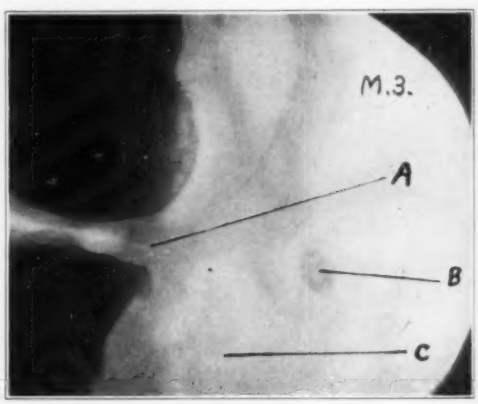

FIG. 31

Fig. 30: Arthrogram showing View M.4, following meniscectomy. *A*, Small rim remains.

Fig. 31: Arthrogram in View M.3, showing lesion of medial meniscus and semimembranosus bursa, containing loose body. *A*, Damaged medial meniscus; *B*, loose body; *C*, semimembranosus bursa. Arthrotomy was not performed in this case.

which one end of the tear has become separated and secondary deformation of the tag has occurred. If the tear is oblique, a horizontal split is seen in the arthrogram. This lesion appears to occur more frequently in the lateral meniscus. Loose tags arising from the body of the meniscus, however, are more common on the medial side than on the lateral side. The tag itself may not be seen clearly, as it tends to lie across the joint, overlapped by the anterior and posterior articular margins of the tibia. The outline of the meniscus itself is reduced in size and is irregular (Figs. 25-A and 26-A).

4. *Discoid Menisci*: Because the center of the discoid meniscus is very thin, it does not throw a clear shadow and the appearance may suggest that a large meniscus is present with a displaced bucket-handle lesion. Sometimes, however, a definite split can be seen (Fig. 27-A).

5. *"Hypermobile" Lesions*: That hypermobility of a meniscus exists to a degree sufficient to cause symptoms has long been challenged. In the present series, true hypermobility was demonstrated (and proved by operation) on only one occasion. In this case the posterior horn appeared to be detached from the tibial spine. The arthrogram in View M.4 shows the posterior part of the meniscus drawn well out of the joint, although how much of this is really meniscus and how much is synovial membrane is difficult to tell (Fig. 28). At arthrotomy, it could be seen quite definitely that, when the knee was flexed, the meniscus was drawn out of the back of the joint; and, when the joint was extended, the meniscus returned between the articular surfaces. In doing this, it caught on the posterior lip of the tibia and resumed its normal position with an audible click. The meniscus itself was undamaged. Although it is not intended in this communication to discuss the results of treatment, it is interesting that this patient's symptoms were cured by meniscectomy.

FIG. 32

"Skyline" view of patella, showing outline of articular cartilages (*A*), with air between.

In one other patient a similar appearance was obtained in M.4, but the degree of mobility was much less marked (Fig. 29). The meniscus can be seen drawn out of the back of the joint more than is usually the case; there is a pouch of air above and below it. Unfortunately, arthrotomy could not be undertaken in this case.

Other Joint Lesions

Lesions other than those of the menisci can be demonstrated with less accuracy. They are as follows:

Erosion of Articular Cartilage: It is possible to demonstrate only extensive and deep erosion of the articular cartilage. Attempts to demonstrate erosion of the articular surface of the patella have proved more promising with the technique previously described. These results, however, are not included in the present series (Fig. 32).

Loose Bodies: In the present series only two cases of non-osseous loose bodies were shown; both of these were of large size. Small loose bodies, subsequently found in conjunc-

TABLE I

RESULTS IN CASES IN WHICH A LESION WAS DIAGNOSED

Diagnosis by Arthrogram	Number of Knees	Number of Arthrotomies	Number Proved Correct by Arthrotomy	Pathological Findings in Cases of Incorrect Arthrographic Diagnosis	
				Number	Pathological Findings
Tears of medial meniscus	146	138	130	3	No lesion
				2	Synovial tag
				1	No lesion as diagnosed, but lesion found in other meniscus
				1	Loose body
				1	Tear of anterior cruciate ligament
Tears of lateral meniscus	45	43	41	1	No lesion
				1	Synovial tag
Tears of both menisci	21	20	20		
Other lesions	4	4	4		
Totals	216	205	195	10	

tion with other lesions at arthrotomy, were not visible on the roentgenograms. In several knees, loose bodies were demonstrated on the arthrogram when they were not seen on the straight anteroposterior and lateral views, but this was probably due to the number of views taken. It is doubtful whether arthrography helps in the discovery of loose bodies.

Osteochondritis Dissecans: Although this lesion can be seen more distinctly with air in the joint, in all cases the diagnosis had already been established by straight roentgenograms.

Semimembranosus Bursa: Following the injection of air into the joint, the bursa can frequently be palpated clinically and is found in a number of knees in which its presence had caused no symptoms. In one knee, a semimembranosus bursa was seen, which contained a loose body (Fig. 31).

RESULTS

In the present series, 331 knees have been examined by air arthrography. A variety of lesions have been demonstrated,—some with ease and some with great difficulty. At the beginning of the series, the diagnosis was less accurate than it was later, owing to lack of experience in interpretation, which led to a proportion of the errors. No selection of cases was made.

Of the 331 knees which have been examined, lesions were diagnosed in 216 and were not demonstrated in 108. There were seven failures.

Of the 108 knees in which no lesion was found, the clinical signs and history in twenty-one were such that the negative diagnosis was considered to be in doubt and an arthrotomy was performed. Of these cases, sixteen were found to have no lesion and five to have a lesion of some type.

Table I presents the results in the 216 knees in which a lesion was diagnosed. Two hundred and five came to operation and, of these, 195 were found to have lesions, as diagnosed. There were 130 lesions of the medial meniscus and forty-one lesions of the lateral meniscus. There were twenty double lesions and four other lesions, such as osteochondritis dissecans.

Of the ten in which a positive diagnosis was made incorrectly, four had no lesions, three had synovial tags and hypertrophied retropatellar pads of fat, one had a loose body, one had a torn anterior cruciate ligament, and one had a lesion in the meniscus opposite that in which it was diagnosed.

In twenty-one knees there were double lesions, twenty of which came to operation. In twelve of these, the second lesion was unsuspected before the arthrogram was made.

Excluding the seven failures, therefore, there was an apparent inaccuracy of fifteen (ten errors of commission and five of omission) in 324 knees, or an inaccuracy of 4.5 per cent. This figure may not be exact, as there is no certain way of knowing how many of the negative diagnoses were correct, or whether the diagnoses were accurate in the eleven patients upon whom operation was not carried out.

All but one of the seven failures were due to the presence of fluid in the joint. It would appear that an excess of fluid is a contra-indication to air arthrography. Aspiration of the fluid, before the injection of air, is insufficient. Turning the knee, when taking the views, so that the part of the meniscus being x-rayed is uppermost and therefore away from the fluid, is not entirely satisfactory. Synovial fluid is viscous and tends to cling to the menisci, thus obscuring their outlines in a certain number of cases. It is therefore more satisfactory to allow the fluid to be absorbed by rest and immobilization.

Lesions other than those of the menisci are much more indefinite, as articular cartilage shows up rather indistinctly and non-osseous loose bodies, unless of considerable size, are not usually seen. Only four lesions of this type, unassociated with lesions of the menisci, were seen in this series.

There have been no severe reactions following the injection of air into the knee joint; although, in about one quarter of the knees investigated, some effusion was produced. This did not persist for more than a few days and did not give rise to subsequent symptoms. In all cases in which the erythrocyte sedimentation rate was determined, it was normal. The effusion was probably the result of a mild irritative effect of the air. The air is usually completely absorbed in from four to seven days.

CONCLUSIONS

1. In the large majority of injuries of the menisci, the diagnosis can be made on clinical grounds alone. Air arthrography is, however, useful as an aid to diagnosis, particularly in mixed lesions, such as tears of the anterior cruciate ligament associated with tears of the menisci, or simultaneous lesions of both menisci. The diagnosis of lesions of the medial meniscus is simpler than the diagnosis of lesions of the lateral meniscus.

2. Arthrography is of less value in the diagnosis of other lesions of the knee joint, but is occasionally useful.

3. Arthrography affords interesting information regarding the movements of the menisci during flexion and extension of the knee. These movements can be studied both with roentgenograms and by fluoroscope. When the knee is flexed, the medial meniscus tends to be drawn backward out of the joint, and for this reason is not trapped.

4. Although the injection of air into a joint may produce a transient effusion, this is in no way harmful. Arthrography is a safe and simple procedure, when done with full aseptic precautions.

NOTE: The author is indebted to Air Commodore H. Osmond Clarke and to Wing Commander A. A. Butler for their advice and criticism.

REFERENCES

CULLEN, C. H., AND CHANCE, G. Q.: Air Arthrography in Lesions of the Semilunar Cartilages. British J. Surg., **30**: 241–245, 1943.

DITTMAR, O.: Der Kniegelenks-Meniskus im Röntgenbilde. Röntgen-Praxis, **4**: 442–445, 1932.

EVANS, W. A., JR.: The Roentgenological Demonstration of the True Articular Space. With Particular Reference to the Knee Joint and the Internal Semilunar Cartilage. Am. J. Roentgenol., **43**: 860–864, 1940.

HAUCH, P. P.: Pneumoröntgenography of the Knee Joint. British J. Radiol., **17**: 70–74, 1944.

KLEINBERG, S.: The Injection of Oxygen into Joints for Diagnosis. Am. J. Surg., **35**: 256–261, 1921.

QUAINTANCE, P. A.: Pneumoroentgenography of the Knee Joint. An Analysis of Fifty Cases. J. Bone and Joint Surg., **20**: 353–362, Apr. 1938.

RUBIN, E. L.: The Delineation of Articular Cartilage by X Rays without the Aid of Contrast Media. British J. Radiol., **12**: 649–657, 1939.

SOMERVILLE, E. W.: Air Arthrography in the Diagnosis of Internal Derangement of Knee-Joint. Proc. Royal Soc. Med., **36**: 663–664, 1943.

DISEASES AND DEFECTS OF THE MUSCULOSKELETAL SYSTEM IN AIR-CREW TRAINEES

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The following study is based on a survey of diseases and defects of the musculoskeletal system observed in 344,134 men who were examined for air-crew training (as bombardier, navigator, or pilot) at Army Air Forces Classification Centers and Army Air Forces Basic Training Centers. The group upon which these examinations were done was not a cross section of the average population. It was a selected population in the following respects: The ages ranged from seventeen to twenty-seven years; the men examined were presumably healthy; and they had been screened by at least one previous physical examination. The men were very anxious to pass the examination, and this caused them to conceal defects and deny symptoms.

TABLE I

DISEASES AND DEFECTS OF THE FOOT

Congenital defects	6
Arthritis	
Specific	2
Non-specific	5
Traumatic	1
Other types	3
Osteomyelitis	
Specific	1
Non-specific	4
Osteochondritis	1
Ankylosis	
Postinfectious	1
Posttraumatic	2
Posttraumatic deformity	5
Amputation of portion of foot	8
Fracture	
Malunion	1
Non-union	6
Paralysis of muscles	2
Hallux valgus	8
Hallux varus	1
Hammer toes	13
Pes planus	
Second degree, non-symptomatic	3
Second degree, symptomatic	191
Third degree, non-symptomatic	43
Third degree, symptomatic	181
Rigid type	4
Pes cavus	34
Other diseases or defects	26
Total	552

METHOD OF EXAMINATION

The physical examination carried out on this population was that prescribed by Army regulations for flying personnel. This examination is intended to be highly standardized and rigorous, but, under conditions of mass selection, it necessarily varies in uniformity and quality.

The examination of the musculoskeletal system was done with the examinees stripped.

TABLE II

DISEASES AND DEFECTS OF THE JOINTS AND SYNOVIAL MEMBRANES

GENERAL	
Congenital defects	8
Arthritis	
Acute infectious, non-gonorrheal	12
Acute infectious, gonorrheal	4
Rheumatoid	8
Atrophic	11
Hypertrophic	24
Posttraumatic	31
Osteo-arthritis	5
Osteochondritis	15
Ankylosis	
Postinfectious	5
Posttraumatic	19
Posttraumatic deformity	7
Calcification of joint capsule	4
Limitation of motion due to disease and defects of soft parts, alone or in combination	46
Luxation	2
Subluxation	11
Recurrent sprains	35
Other diseases or defects	43
SHOULDER	
Recurrent dislocation	24
HIP	
Legg-Perthes disease	8
Coxa vara	3
Coxa valga	1
Slipped epiphysis	1
Posttraumatic deformity of joint	5
KNEE	
Legg-Perthes disease	2
Fractures and dislocations of semilunar cartilage	68
Recurrent dislocation of semilunar cartilage	27
Operation for fracture or dislocation of semilunar cartilage	7
Laceration of cruciate ligaments	9
Genu varum	1
Relaxation of ligaments and joint capsule	24
Recurrent dislocation of patella	2
Fracture of patella with non-union	2
Total	474

A group of examinees, the size of which depended upon the area of the examining room and the number of medical examiners available, stood facing the examiners in staggered lines so as to allow full inspection of each individual. Scars, deformities, and abnormalities of the musculoskeletal system were recorded. The examinees then performed a series of exercises, designed to disclose abnormalities of function. Under ideal conditions, this close search for deformities and the tests for range of motion of joints, muscle coordination, strength, and agility should have made manifest all but a minimum number of structural defects, weaknesses, and musculoskeletal abnormalities. In practice, this ideal standard could not be reached when it was necessary to examine large groups.

Among the 344,134 examinees, a total of 1,856 (5.39 per 1,000) disqualifying defects were found in 1,561 men (4.53 per 1,000). The results of the examinations are shown in Tables I to VIII, inclusive.

ANALYSIS OF FINDINGS

Chart I shows the relative frequency of defects, according to the categories in Tables I to VIII.

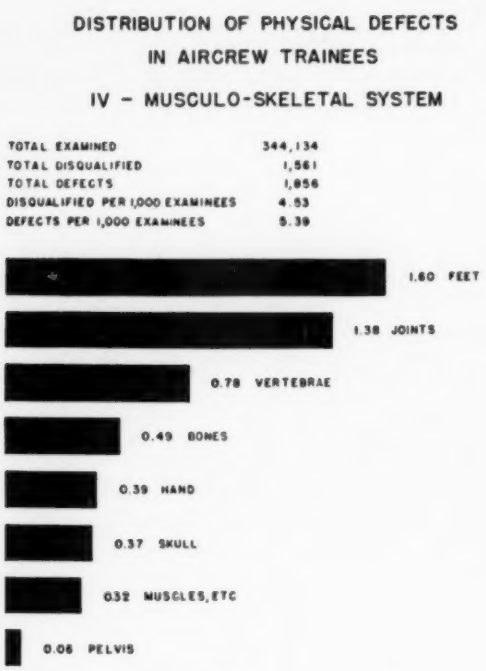

CHART I

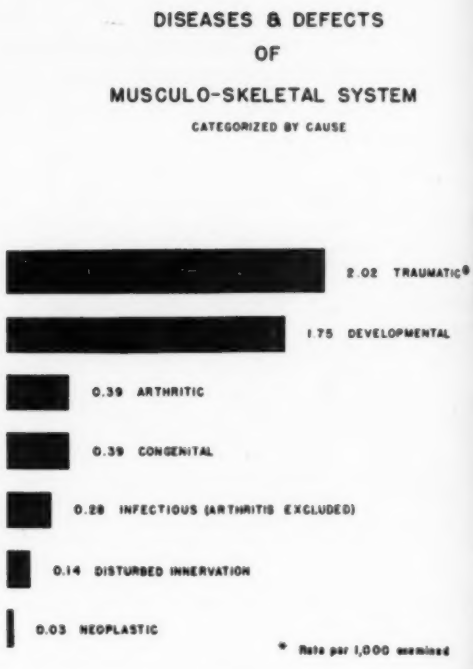

CHART II

TABLE III

DISEASES AND DEFECTS OF THE VERTEBRAE

CONGENITAL	
Spina bifida	
Occulta	19
Vera	4
Spondylolisthesis	31
Spondylosis	3
Hemivertebra	7
Sacralization of lumbar vertebra	9
Other congenital defects	11
INFECTIOUS	
Osteomyelitis, non-tuberculous	2
Osteitis	2
Spondylosis	2
Osteochondritis	3
Other infections	4
TRAUMATIC	
History of fracture	87
Fracture-dislocation	2
Dislocation	8
Posttraumatic deformity	10
Other defects	16
CAUSE UNDETERMINED	
Scoliosis	21
Kyphosis	11
Herniation of nucleus pulposus	12
Hypertrophy of ligamentum flavum	1
Symptomatic lordosis	2
Total	267

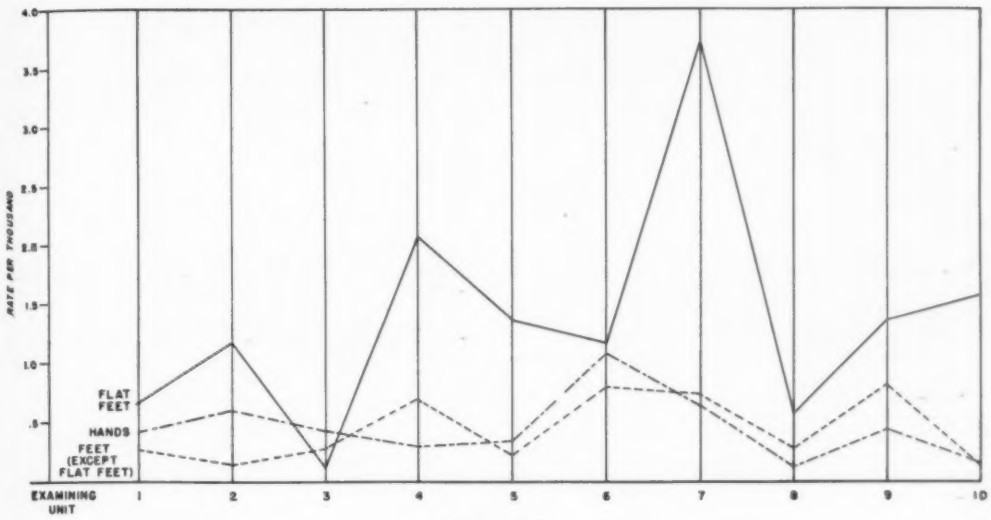

CHART III

TABLE IV

DISEASES AND DEFECTS OF THE BONES OF THE EXTREMITIES

Congenital deformities	11
Osteitis	2
Periostitis	1
Osteomyelitis	
Non-tuberculous	46
Tuberculous	1
Osteochondritis	2
Fracture	
Malunion	25
Non-union	30
Internal fixation	1
Synostosis	3
New growth	10
Other diseases or defects	35
Total	167

Chart II shows the relative frequency of these defects and diseases, according to the following categories:

1. Defects due to injury.
2. Defects of structural development.
3. The arthritides.
4. Congenital defects.
5. Defects due to infection.*
6. Defects of innervation.
7. New growths.

RESULTS

The interpretation of the physical findings was subject to differences in clinical judgment and in the application of pertinent regulations. These factors resulted in variations of the disqualification rates for various conditions by different examining units. Such ill-defined conditions as flat-foot were subject to the greatest range of variation.

Chart III illustrates the variation in disqualifications by different examining units

* Only one case of tuberculosis of the skeletal system was reported.

TABLE V

DISEASES AND DEFECTS OF THE HAND

Congenital defects	5
Arthritis	
Non-specific	2
Atrophic	2
Other types	1
Osteochondritis	3
Ankylosis	
Postinfectious	3
Posttraumatic	12
Deformities	
Postinfectious	5
Posttraumatic	20
Amputation of portions of hand	69
Fractures	
Malunion	2
Non-union	1
Paralysis of muscles	3
Other diseases or defects	7
Total	135

TABLE VI

DISEASES AND DEFECTS OF THE SKULL

Congenital defects of bones of vault	1
History of fracture	114
History of craniotomy	4
Traumatic defects	8
Other diseases and defects of vault	1
Other diseases and defects of bones and face	1
Total	129

TABLE VII

DISEASES AND DEFECTS OF THE MUSCLES, TENDONS, FASCIAE, AND BURSAE

MUSCLES	
Congenital defects	17
Myositis	14
Posttraumatic deformity	4
Paralysis	6
Atrophy	38
Other diseases or defects	16
TENDONS AND FASCIAE	
Congenital defects of tendons	1
Laceration of tendon	2
Tenosynovitis	2
Other diseases or defects of tendons	4
Diseases or defects of fascia	2
BURSAE	
Chronic bursitis	5
Total	111

for defects of the hands and feet. The ten examining units examined different numbers of men, ranging from 13,500 to 50,000. The numbers of examinees were large enough to exclude factors of chance. The rates of disqualification for flat-foot varied from 0.11 to 3.74 per 1,000 in different examining units. The disqualification rates for other defects of the foot and for defects of the hand showed no such wide variation.

TABLE VIII

DISEASES AND DEFECTS OF THE PELVIS

Osteomyelitis	1
Fracture	
Non-union	3
Malunion	2
Other diseases or defects	13
Total	19

TABLE IX

CONDITIONS REGARDED AS "CAUSES" OF BACKACHE

Spina bifida	
Occulta	19
Vera	4
Spondylolisthesis	31
Spondylosis	3
Hemivertebra	7
Sacralization of lumbar vertebra	9
Osteitis of vertebra	2
Spondylosis	2
Osteochondritis of vertebra	3
Fracture of vertebra	87
Fracture-dislocation of vertebra	2
Dislocation of vertebra	8
Posttraumatic deformity of vertebra	10
Scoliosis	21
Kyphosis	11
Total	219

TABLE X

	White Selectees (*Per 1,000*)	Air-Crew Applicants (*Per 1,000*)
Rejections for musculoskeletal defects*	22.6	3.41
Rejections for flat-foot	4.9	1.23
Rejections for other foot defects	1.4	0.38

* Excluding defects of the feet for both groups, and a history of skull fracture in the case of air-crew applicants.

These findings suggest that, among medical officers, there is common agreement neither as to what constitutes flat-foot, nor as to the degree of flat-foot which should be considered disqualifying. The term "flat-foot" will remain unsound semantically until meticulous definitions of each degree of flat-foot are generally agreed upon. In the present state of confusion, it might be better to discontinue the use of this phrase and to substitute such terms as "foot strain", "torsion of the talus", "relaxed plantar ligaments", "pronation of the foot", and "structural weakness of the foot". These terms at least suggest an attempt at diagnosis, and they can be given more meaning by grading the conditions as mild, moderate, or severe. Such diagnoses are open to criticism, but they are an improvement on the term flat-foot, which merely describes certain anatomical variations, as interpreted by varying schools of orthopaedic thought.

Table IX shows the number of cases of various conditions sometimes considered to be "causes" of backache. When roentgenograms reveal such defects as those listed in Table IX, it has become customary to regard the findings as confirmatory evidence of the

organic causes of backache. These air-crew applicants may be presumed to have been free of backache, or at least to have been confident that they could "get by" during their training; yet they showed a moderate number of the "causes" of backache. Since the skeletal system was not examined by roentgenogram routinely, but only when there was special indication, it is certain that the "causes" of backache are far more common than were reported for these examinees. There is strong evidence to suggest that frequently these defects exist without causing symptoms, and that their presence is not conclusive proof that a complaint of backache has an organic basis.

It does not necessarily follow that, because an individual with a backache is found to have an abnormality of the vertebral column, which existed before his symptoms developed, his backache is caused by the abnormality. Despite the presence of such roentgenographic findings, the backache may be due to other causes, such as prostatitis or psychoneurosis.

A detailed comparison between the disqualifications per 1,000 among air-crew applicants and the rejections of white Selective Service registrants, as reported by Rowntree, McGill, and Edwards [1], is not possible, due to differences in the methods of recording the defects. The comparisons in Table X, however, indicate that the air-crew applicants were a highly selected group.

The relatively low rate of disqualification for musculoskeletal defects justifies the policy of screening applicants for physical defects before they are sent to air-crew examining centers.

1. Rowntree, L. G.; McGill, K. H.; and Edwards, T. I.: Causes of Rejection and the Incidence of Defects Among 18 and 19 Year Old Selective Service Registrants. J. Am. Med. Assn., **123**: 181–185, 1943.

ACUTE INSTABILITY OF THE LIGAMENTS OF THE KNEE AS A RESULT OF INJURIES TO PARACHUTISTS

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Medical Corps, Army of the United States

Modern military training has greatly increased the incidence of traumatic instability of the knee. This has been especially evident at Fort Benning, a Post devoted to advanced infantry training, where the violent combat exercises and obstacle courses in Officer Candidate School, as well as the hazards peculiar to parachute jumping, make injuries of the ligaments of the knee a source of many hospital admissions. These injuries are serious, not only from the point of view of the prolonged initial disability, but also because of the high incidence of late symptoms. Too frequently, these patients complain of persistent pain, weakness, and instability in their knees and show an increased susceptibility to joint effusions after subsequent trivial injuries. The present study was undertaken with the aim of minimizing these residual symptoms.

The literature on injuries to the ligaments of the knee is remarkable for the contradictions and divergent statements on all phases of the subject. Even the surgical anatomy is variably interpreted, as described by Brantigan and Voshell in 1941. Within the past five years, however, a number of outstanding investigations [1,3,4,8] have crystallized certain facts from the mass of diversified opinions, and there is now general agreement on at least the following points:

1. The knee is a complicated weight-bearing joint with a combined hinge, gliding, and rotary action.
2. The joint is supported by active muscle power, as well as by the ligaments.
3. The ligaments also serve to direct the muscle power.
4. The ligaments are mutually reinforcing and function as a team, so that the loss of a single ligament does not produce a major instability.
5. Solitary ligaments are rarely injured.
6. The knee should be considered as a functional unit.

This concept of the knee as a functional unit (the "physiologic joint" of Palmer) is fundamental. Much of the confusion in the literature can be traced to neglect of this principle and to preoccupation with the individual ligaments or elaborate surgical reconstructions, with insufficient emphasis on the ultimate functional recovery of the knee as a whole.

The purpose of this paper is twofold: first, to describe a new mechanism of injury causing instability of the ligaments of the knee; and, second, to report the results of conservative treatment in a large series of cases.

CLINICAL MATERIAL

This series comprises eighty-five cases of acute instability of the ligaments of the knee treated at this Post during the past three years. In every case, abnormal mobility was demonstrated clinically; if any doubt existed, or if the initial examination did not specifically describe instability of the joint, the case was excluded from consideration. Also excluded were such acute derangements of the knee as "sprains" and effusions without instability, dislocated patellae, ordinary meniscal tears, and unstable knees due to depressed fractures of the tibial plateau. Late cases of instability were similarly excluded, although a few of them were followed in order to observe the effects of intensive quadriceps exercises, and to study the incidence of degenerative changes in the joint. No attempt was made to use these cases as controls.

In Table I the cases are arranged according to the cause of injury, the severity of

TABLE I

ETIOLOGY, TYPE, AND SEVERITY OF INSTABILITY OF LIGAMENTS OF THE KNEE

Mechanism of Injury	Number of Cases	Side		Predominant Instability			Severity			
		Right	Left	Abduction	Adduction	Other	Mild	Moderate	Severe	Undetermined
Parachute injuries:										
Opening shock	59	10	49	59	0	0	5	8	30	16
Landing impact	8	1	7	5	2	1	2	2	2	2
Obstacle courses	9	2	7	8	1	0	1	4	0	4
Sports	5	3	2	5	0	0	2	1	0	2
Miscellaneous	4	2	2	3	0	1	1	0	0	3
Totals	85	18	67	80	3	2	11	15	32	27

injury, and the type of instability. Since the ligaments are mutually reinforcing, it is impossible to determine from clinical examination of a given knee exactly which ligament or set of ligaments has been injured; the pattern of instability has therefore been described in terms of the direction of abnormal mobility. The overwhelming majority are abduction injuries, but few of them show a pure, unmixed instability. The usual clinical picture is a diffuse instability in more than one axis, and the most common clinical pattern is a "severe-abduction-plus-moderate-anterior" instability, involving the left knee five times as frequently as the right knee. Other types were rare; one complete anterior dislocation and three adduction injuries were observed.

The severity of injury is tabulated by measuring the degrees of angular widening of the joint space, as compared with the patient's opposite knee (Figs. 5-A and 5-B). This is more satisfactory than West's method of recording the "spread" of the joint space in millimeters, since it takes into account the appreciable laxity of some perfectly normal knees and is less subject to roentgenographic distortion. To facilitate the measurements, an adjustable hinged frame was constructed, on which the thighs were strapped together; roentgenograms were made while the legs were abducted simultaneously.

The following standards are suggested for gauging lateral instability:

ANGULAR WIDENING OF THE JOINT SPACE

Position of Knee	Mild (*Degrees*)	Moderate (*Degrees*)	Severe (*Degrees*)
Full extension	0 to 2	3 to 5	Over 5
Semiflexion (15 degrees)	0 to 4	5 to 10	Over 10

The following standards are suggested for gauging anteroposterior instability:

TIBIAL SHIFT

Position of Knee	Mild (*Millimeters*)	Moderate (*Millimeters*)	Severe (*Millimeters*)
Flexed to 90 degrees	0 to 4	5 to 10	Over 10

These numerical values for "mild", "moderate", and "severe" were established arbitrarily. Although some investigators may feel that they are too high or too low for a particular situation, they at least fill the need for a concise and objective basis for clinical examination. Throughout this study, every effort was made to secure uniformity of obser-

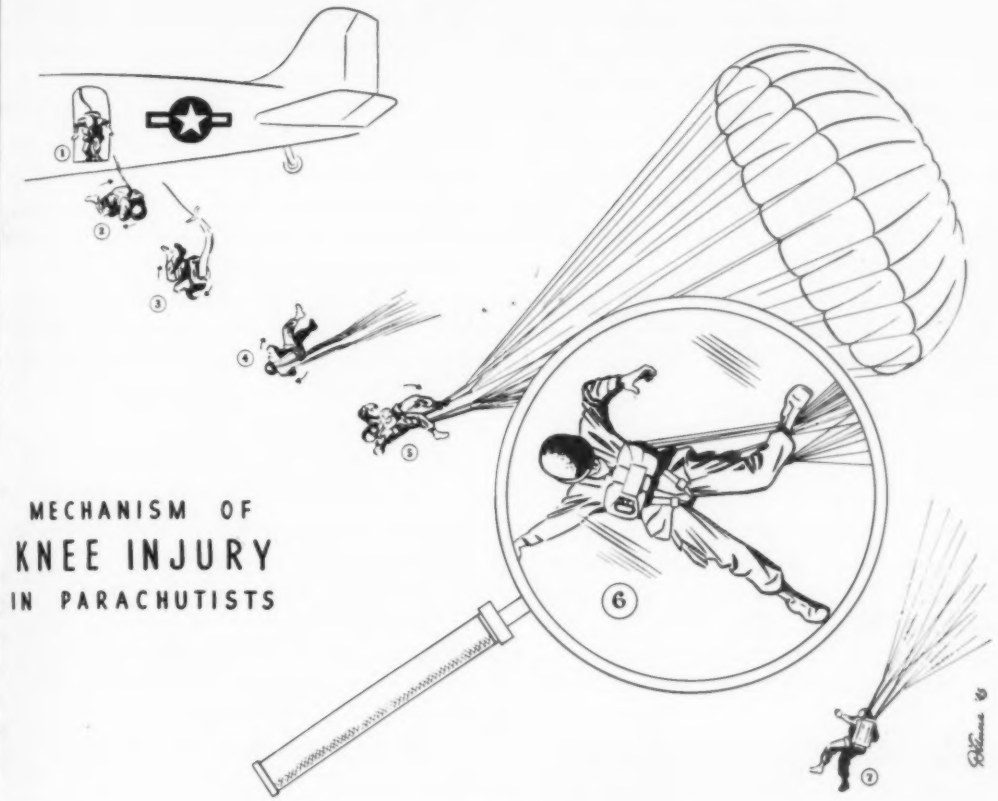

FIG. 1

Diagrammatic sequence of events in the "opening-shock" parachute injury. At phase No. 6, the left lower extremity is abducted by the taut suspension lines, which tear the tibial collateral ligament. The opening shock is a force of considerable violence, occasionally causing fractures of the shaft of the femur or separation of the symphysis pubis.

vations by systematizing the method of examination and adhering to objective standards. Consistency in reporting results was further assured by the fact that the authors personally treated 80 per cent. of the patients and followed their progress at monthly intervals, as long as they remained at Fort Benning.

MECHANISM OF INJURY

The majority of the patients were student parachutists who injured the left knee in the "opening-shock" phase of the parachute jump. Although this unique mechanism of injury concerns primarily the military surgeon, so many cases have accumulated that the sequence of events should also be of general orthopaedic interest.

Instead of leaving the plane in the approved feet-first, feet-together position, the parachutist dives out headfirst and is carried by his own momentum into a left-oblique somersault. As he tumbles forward, his left leg becomes entangled in the slack suspension lines of his parachute (Fig. 1); and then, when the canopy snaps open in mid-air, the left knee is wrenched violently upward and sideways.* The pain is excruciating; the jumper feels as if his knee were dislocated. He usually manages to land with his weight on the uninjured limb, without much additional pain; and then he either limps away or is picked up by medical corpsmen and transported to the hospital.

*The C–47 airplane has a single exit on the port side. This is undoubtedly the reason for the preponderance of injuries to the left knee in the opening shock. The definite lateralization to the left knee following injuries produced by other mechanisms is not explained so readily.

This composite history has been substantiated by experienced instructors at The Parachute School [11], and is further confirmed by the presence of brush burns on the leather along the medial aspect of the jumper's left boot, indicating where the suspension lines scraped across and applied the abducting force (Fig. 2).

The actual parachute landing corresponds to a free fall of about fifteen feet; but, due to uneven terrain, wind drift, and parachute oscillation, the nature of the impact is highly unpredictable. Most parachute injuries occur upon landing [7,13]; but, strangely enough, severe tears of the ligaments of the knee are relatively rare at this time, and they do not conform to such a uniform clinical pattern as opening-shock injuries.

Very few of the injuries in this series were produced by the more conventional mechanisms. Six per cent. were due to football and other sports, and 10 per cent. were incurred on obstacle courses, generally as the result of jumping from a height. These injuries tended to be relatively minor.

EXAMINATION AND DIAGNOSIS

As stated earlier, the pathognomonic feature of these injuries is abnormal mobility of the knee. In most cases, however, the instability was evidently overlooked during the initial examination, and the patient was usually admitted to the hospital with the diagnosis of internal derangement of the knee or traumatic synovitis, with no hint of the serious ligamentous damage. This failure to recognize the true nature of the lesion is understandable, since frequently the knee may be too painful to permit deliberate testing for instability, or the instability may be masked by effusion or muscle spasm. It is true, nevertheless, that a properly performed clinical examination will reveal the diagnosis. Several characteristic features distinguish the lesion: The patient walks guardedly, if at all; he observes his footing carefully and, when moving to the examining table, he cradles his injured limb over the good one. He gives a history of severe, direct violence, in contrast to the relatively trivial injuries which cause meniscal lesions. Typically, he complains that the knee "buckles inward" when he missteps. The knee shows soft-tissue swelling, tenderness, and frequently ecchymosis over the tibial collateral ligament, generally maximum at its femoral insertion. Full extension is prevented by pain and spasm, rather than by organic block, as is the case with dislocated menisci. The amount of intra-articular fluid is variable; in the more severe injuries less fluid accumulates, since it drains through the capsular tear and escapes into the soft tissues. In recent, severe injuries, the torn structure is often palpable as a loose, tender, subcutaneous mass along the course of the tibial collateral ligament.

FIG. 2

Actual brush burns on the parachutist's left boot. Compared with Fig. 1. (*Photo by U. S. Army Signal Corps.*)

Since the demonstration of abnormal mobility determines not only the diagnosis, but also the treatment and prognosis, the technique of examination merits special consideration. The ligaments are not considered individually, but stability is evaluated in terms of functional loss. Figure 3 illustrates the method of determining abduction instability, which is the type most frequently encountered. This is measured first in semiflexion—the position of effort—and then with the knee extended to the normal standing position. Adduction instability is estimated similarly. The knee is then tested for genu recurvatum, and

it is finally relaxed in 90 degrees of flexion to measure anteroposterior instability.

If the knee is too painful to permit adequate relaxation, some form of anaesthesia is recommended by Böhler, by Palmer, and by West. The authors prefer a low spinal anaesthesia, consisting of fifty milligrams of novocaine; this abolishes pain and reflex muscle spasm, yet preserves enough voluntary muscle power to facilitate the application of a cast. With the patient thus relaxed, examination can be deliberate and unhurried. The knee is tested for all types of instability; it is flexed through a full range of motion to rule out organic block; and, if necessary, fluid is aspirated.

FIG. 3

A convenient position for eliciting abduction instability. Relaxation of the thigh muscles is essential for an adequate examination.

TREATMENT

The present treatment is based on Böhler's dictum that the ligaments of the knee, in common with ligamentous structures elsewhere, unite satisfactorily if they are immobilized long enough in the proper position. Accordingly, the patients are immobilized in plaster casts from toes to groin; the knee is maintained in varus position (or other corrective position, depending upon the type of instability) and in about 30 degrees of semiflexion. This relieves the major tension from the capsule and from the cruciate and collateral ligaments, and is the most comfortable position for an injured knee. It is expedient to apply the cast in two sections; the lower half is allowed to harden before the knee and thigh are incorporated. In this way, the unstable knee is easier to control, and accurate alignment of the joint is assured.

The duration of immobilization varies according to the severity of the injury. After three or four weeks, the knee is stable enough in general to permit weight-bearing; and the initial cast is replaced by a snug walking cylinder, which holds the knee in 5 degrees of flexion. The patient wears this cylinder for another three to five weeks; immobilization is usually discontinued at the end of from six to ten weeks.

From the very beginning of treatment, a continuous program of exercises is maintained in order to preserve the tone and substance of the thigh musculature. Some quadriceps atrophy inevitably occurs while the cast is in position, and the average limb shrinks one and one-half inches in circumference, as compared with the opposite thigh; but, as soon as the cast has been removed, exercises are intensified to make good this loss. Each patient is required to devote an hour a day to supervised quadriceps exercises, starting with simple flexion and extension of the knee in bed, and progressing through knee bends, leg raising, chair climbing, weight lifting, running, and cross-country bicycle rides, to the limit of his power and endurance. Pain alone is not regarded as a contra-indication; in fact, the only valid reason for suspending, or even decreasing, the quadriceps exercises is the presence of soft-tissue induration or of chronic joint fluid, which increases after a provocative test. Barring such a complication, however, exercises are pursued as energetically as possible. The more effort the patient expends, the more rapid is his recovery (Chart I)[9,12,14].

In connection with the problem of support for the knee after the cast has been removed, a wide variety of appliances—from adhesive strapping to steel knee cages—have been advocated; in the patients described here, however, no supports were used other than a Thomas heel with a quarter-inch medial wedge. Hinged casts and braces are not physio-

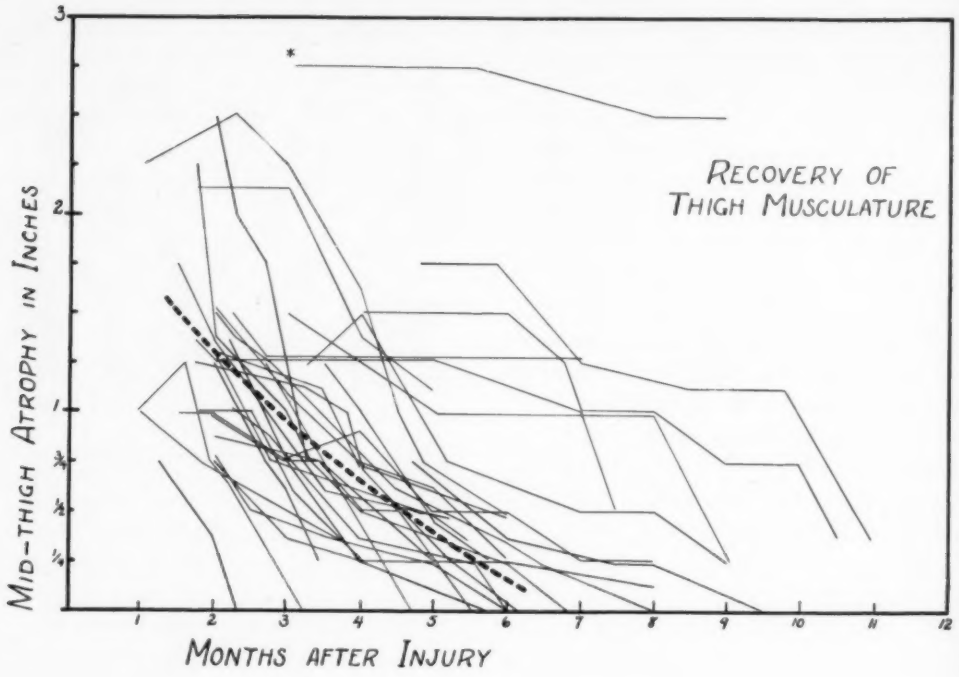

CHART I

Composite graph of the rate of quadriceps recovery in thirty-two cases. There is a remarkably close relationship between the recovery of the thigh musculature and the functional capacity of the knee.

* Case complicated by a diffuse unilateral muscle atrophy, presumably secondary to old poliomyelitis.

logical; no mechanical hinge can support the knee during its complex motions. Bandages and adhesive strapping merely limit the range of motion and promote further muscle atrophy; this in itself is sufficient to condemn them, apart from the fact that they furnish no real support for a weight-bearing joint. The heel wedge, on the other hand, is comfortable; it takes excess strain off the tibial collateral ligament; and it does not induce the patient to favor the limb. Further protection for the injured ligaments is assured by assigning the patient to limited military duty for at least six months from the date of injury, or until healing is considered complete.

ANALYSIS OF RESULTS

In order to secure an objective analysis of end results, and to avoid such vague classifications as "good", "fair", and "poor", the authors have worked out a system of evaluating the functional capacity of the knee in terms of twelve specific clinical criteria. These criteria are listed in Table II and are explained briefly as follows:

1. *Pain:* The patient is questioned regarding such symptoms as pain on twisting movements, aching at night after prolonged exercises, and pain in inclement weather. Individual pain tolerance is necessarily a factor here.

2. *Endurance:* This can be estimated objectively on the basis of measured performance. The standards are high; endurance is not considered normal in a young person unless he can walk twelve or fifteen miles.

3. *Agility:* This is considered apart from endurance. Frequently one finds patients who can work all day long, while standing, but can no longer run or engage in sports.

4. *Quadriceps Atrophy:* This mid-thigh measurement actually includes all the thigh muscles, but clinically the quadriceps manifests more atrophy than the others. It is meas-

ured as the difference in circumference between the two thighs; and it is an extremely significant finding, as will be explained later.

TABLE II

CLINICAL CRITERIA AND STANDARDS FOR EVALUATING THE FUNCTIONAL CAPACITY OF THE KNEE

Criterion	Quantitative Rating			
	1	2	3	4
Pain (P)	None	Slight	Moderate	Severe
Endurance (E)	Normal	Walk of 5 to 10 miles slow trot of 1 mile	Walk of 3 to 5 miles; slow trot of ½ mile	Walk of less than 3 miles
Agility (A)	Normal	Cross-country running; short-stop sports; few symptoms	Cross-country walking; can run on level ground	Cannot run on level ground
Quadriceps atrophy (Q)	None	Up to ½ inch	¾ to 1¼ inches	1½ inches or more
Subjective instability (S	None	Slight	Moderate	Severe
Sagittal instability (AP)	None	0 to 4 millimeters	5 to 10 millimeters	Over 10 millimeters
Abduction instability in semiflexion (FL)	None	0 to 4 degrees	5 to 10 degrees	Over 10 degrees
Abduction instability in extension (EX)	None	0 to 2 degrees	3 to 5 degrees	Over 5 degrees
Intra-articular fluid (F)	None	Slight and transient	Slight and chronic, or moderate and transient	Marked or persistent
Clicking (C)	None	Slight or intermittent clicking	Moderate and persistent	Painfully severe and constant
Range of motion (M)	Normal	Flexion to 140 degrees	Flexion to 120 degrees	Less than 90 degrees of flexion
Determination and attitude (D)	Normal	Less than optimum effort and perseverance	Discouraged and uncooperative	Markedly defective attitude; exaggerated disability

Instability is evaluated under four separate headings:

5. *Subjective Instability:* This is graded according to the patient's complaints of "slipping", "going out of place", or "buckling" of the knee, with due consideration for the causative activity.

6. *Sagittal Instability:* This is also called anteroposterior instability, or "drawer action".

7. *Abduction Instability in Semiflexion:* This is measured roentgenographically, with the limb forcibly abducted and the knee in 15 degrees of semiflexion. Too much flexion is to be avoided, since it introduces excessive torque on the femur.

8. *Abduction Instability with the Knee in Extension:* This is measured roentgenographically, with the knee in the normal standing position, not in hyperextension.

9. *Intra-Articular Fluid:* Both the amount of fluid and the frequency of recurrence are considered here.

10. *Clicking:* This term includes various cracking and snapping sounds. No true locking has been observed in this series of cases.

11. *Range of Motion:* This is measured in degrees of flexion, starting from 0 degrees at full extension.

12. *Determination and Attitude:* The patient's cooperation, perseverance, and determination to get well are highly important factors. In the Army, as with industrial compensation, the secondary gain derived from disability frequently influences and prolongs the ultimate recovery.

FIG. 4-A

FIG. 4-B

FIG. 4-C

Roentgenograms illustrate the development of a shadow typical of so-called Pellegrini-Stieda disease, following abduction injury. Clinically, this case presents a slight prominence at the site of calcification; occasionally this prominence becomes tender after repeated traumata, but otherwise no symptoms are produced. Stability of the knee is good; there is no limitation of motion. The patient is now an instructor at The Parachute School and is extremely active physically.

While other criteria might well be included in this list, we feel that those selected are representative enough to furnish an integrated picture of the functional recovery of the knee. By measuring the criteria objectively, in numerical units, according to rigid clinical standards, the inconsistencies arising from reliance upon personal judgment alone have been reduced to a minimum. Practical application of this method is illustrated in the case reports; in the authors' experience it has provided a convenient, sound basis for comparing end results.

In evaluating the over-all results of conservative treatment, the first consideration, naturally, is the recovery of stability of the knee. Healing of the ligaments in the abduction injuries has been very satisfactory. In the last sixty consecutive cases, including all degrees of injury, the final roentgenographic measurements demonstrate that fully 95 per cent. recovered with less than 5 degrees of residual instability*. Even the most extreme abduction injuries, with apparently complete rupture of the tibial collateral ligament, showed only 2 or 3 degrees of residual abduction instability (Cases 1 and 2). Moderate injuries healed with a final average of 2 degrees, and the mild cases showed even less than that. These minor degrees of instability are tolerated quite well, and do not interfere appreciably with the patient's endurance or agility. Only when the residual abduction instability exceeds 5 degrees do the symptoms become troublesome. Such patients, who comprise approximately 5 per cent. of this series, complain of weakness, recurrent effusions, and pain to such an extent that they are no longer fit for military service. As a clinical rule of thumb, therefore, it may be stated that abduction instability in excess of 5 degrees is unsatisfactory; less than this is perfectly compatible with a good functional result.

End results in other types of instability were also favorable, although the number of cases is too small to afford dependable statistics. Adduction instability has proved relatively less disabling than abduction lesions of equal degree, because of the closer anatomical supporting action of the tensor fasciae latae and the iliotibial band (Case 6). With regard to anterior and posterior instability, in the more pronounced cases (with more than one centimeter of drawer action) the patients often complain of slipping sensations; but symptoms are generally not troublesome unless abduction weakness is also present (Case 3). In summary, while the results of conservative treatment are overwhelmingly satisfactory in so far as stability is concerned, it must be kept in mind that stability alone does not wholly determine the functional result.

Of all the criteria listed, the most reliable single index of functional recovery is the amount of quadriceps atrophy. A sound, firm quadriceps is associated with a good knee; and, conversely, patients with shrunken thighs invariably complain of fatigability, diffuse pain in the knee, and buckling sensations,—the well-known "weak-knee syndrome" described by Palmer. The supporting role of the thigh muscles becomes doubly important when the ligaments are torn, as is shown by the studies of Brantigan and Voshell and of DeLorme; indeed, the functional recovery of these patients is in direct ratio to the quadriceps recovery. Clinical experience has shown that atrophy in excess of three-quarters of an inch is almost invariably accompanied by symptoms; and, when it approaches one and one-half inches, the patient displays so much disability that, even with excellent healing of the ligaments, he cannot be considered to have achieved a good result. This is the reason for insisting upon quadriceps exercises as an essential part of the treatment. Chart I illustrates graphically the actual rate of quadriceps recovery and, with remarkable accuracy, the parallel functional recovery of the knee as a whole. In this series, the average cooperative patient shows full quadriceps recovery in from five to seven months. In some cases a longer time is required, but if the patient shows more than one inch of atrophy at the end of six months, his recovery is considered to be delayed. As indicated in Chart I,

* Roentgenographic measurements of residual instability are not available in the earlier cases; however, the clinical estimates of instability in these cases tend to substantiate the figures given.

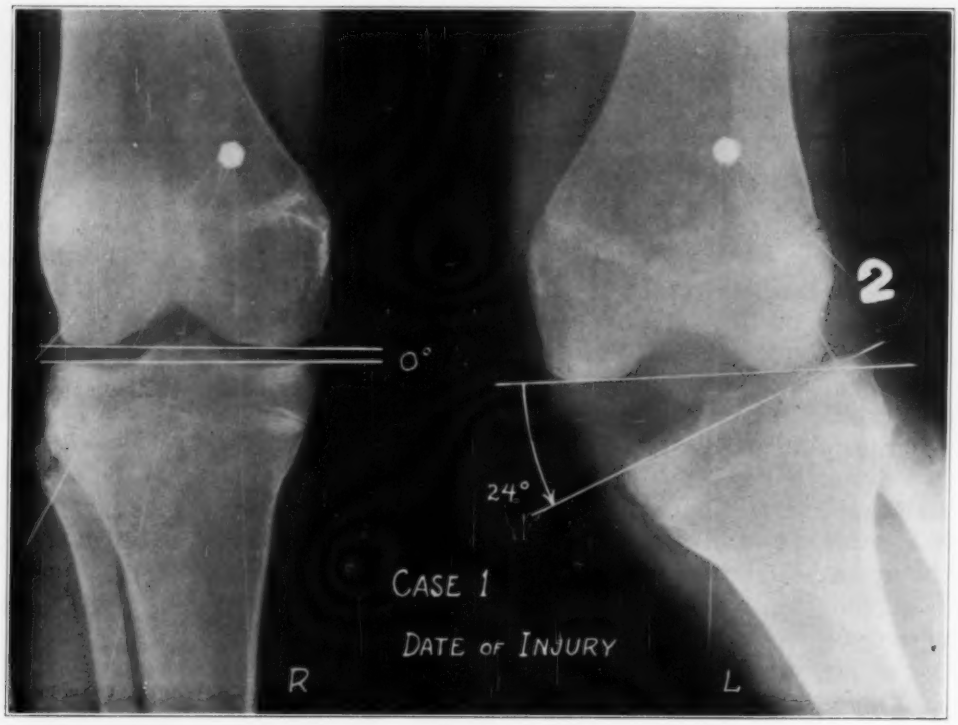

FIG. 5-A

Case 1. Roentgenograms demonstrate severe abduction instability of the left knee in semi-flexion. The right knee is normal.

FIG. 5-B

Ten weeks after injury, very slight residual instability is seen.

six cases fall into this group: One did not improve because of a diffuse muscle hemiatrophy, presumably due to old poliomyelitis; two others were considered generally poor results (see Case 3); in the remaining three cases the atrophy was simply due to laziness and the patient's neglect of the prescribed quadriceps exercises. With proper coaching and more intensive exercises, the response of the quadriceps muscle in these three cases was reflected symptomatically in greater endurance, agility, and freedom from pain (see Case 5).

Intra-articular fluid is rarely a troublesome symptom, since it usually disappears within from four to six months and does not recur. In a small percentage of cases, however, the effusion is unusually persistent, and fluctuates with the amount of physical activity and subsequent trauma (Case 3). Usually, such cases are also unsatisfactory from the point of view of poor intrinsic stability, chronic thickening of the capsular structures, and excessive quadriceps atrophy. They are unduly susceptible to injury, and effusions develop after minor sprains. Careful rehabilitation of the thigh musculature will minimize the episodes of effusion and improve the functional capacity better than will any artificial brace or support.

Limitation of motion has been a negligible problem, because almost all of the patients recover complete extension and normal flexion within six months. Ultimately, every patient except the one with the dislocated knee (Case 7) obtained at least 135 degrees of flexion, which is sufficient for all ordinary pursuits.

A common roentgenographic feature of healing is the development of calcific shadows along the course of the tibial collateral ligament, the so-called Pellegrini-Stieda disease. This complication was present in fully 60 per cent. of our cases. Typically, it first appears in from three to six weeks as a flocculent shadow, which gradually condenses to a curvilinear residue, more or less closely associated with the femoral attachment of the tibial collateral ligament (Figs. 4-A, 4-B, and 4-C). These patients may show persistent tenderness at the site of calcification, and occasionally slight pain on full flexion; but, in the authors' experience, no actual disability has been attributable directly to the lesion, and it is of roentgenographic rather than of clinical importance [6,10].

In order to illustrate specifically the regimen of conservative treatment, the following cases are reported in some detail. They represent a variety of severe injuries of the ligaments, and include examples of both good and poor end results.

CASE REPORTS

Severe Abduction Injury with Good Result

CASE 1. A soldier caught his left boot in the suspension lines of his parachute and experienced violent, numbing pain in his knee during the opening shock. The limb buckled medially on attempted weight-bearing, and he was taken to the hospital with a diagnosis of traumatic synovitis. Examination revealed painful limitation of motion, and diffuse soft-tissue swelling and tenderness along the medial aspect of the left knee. Gross instability was evident, although the exact amount was obscured by muscle spasm. After a low spinal anaesthesia, however, the patient showed extreme instability of the left knee, particularly in semiflexion (Fig. 5-A), as well as slight anteroposterior hypermobility. He had a full range of active motion while under anaesthesia.

He was immobilized for six weeks in a toe-to-groin plaster cast, applied according to the technique previously described, with the knee flexed at 30 degrees and in slight varus correction. This cast was replaced by a walking cylinder, which was employed for four more weeks, and maintained the varus position. During this time, performance of the quadriceps exercises was rather perfunctory and, upon removing the cylinder cast, the patient had excessive atrophy of the thigh (two and one-half inches). The program of muscle rehabilitation was hampered at first by a persistent effusion, but this subsided after several aspirations and thereafter his progress was rapid.

Four months after the injury, stability was very good (Fig. 5-B). There was only 1 degree of residual abduction instability in semiflexion, none in full extension, and only slight anteroposterior hypermobility. The effusion was almost gone. Atrophy was one and three-quarters inches.

At the end of *five months*, there was considerable symptomatic and clinical improvement. The patient was able to walk five miles, but he still felt that the knee was weak when he stepped on uneven

ground. He had a full range of motion. There was very slight swelling; atrophy was three-quarters of an inch.

After *six months,* the knee was subjectively stronger and the patient was able to walk ten miles. He could trot for one mile over uneven ground, with minimum discomfort, and was able to ride a bicycle for long distances. Although the knee still was somewhat unstable when he participated in active sports, such as baseball and volleyball, his agility was improving rapidly. Objectively, the residual instability was minimum. No swelling was apparent, even after prolonged activity. The range of motion was completely normal. Atrophy was one-half inch. His attitude and perseverence were excellent, and he remarked that his knee was "getting stronger all the time".

Using the criteria and standards advocated in Table II, this patient's functional capacity at the end of six months can be condensed into the following formula:

P	E	A	Q	S	AP	FL	EX	F	C	M	D	Disability Rating *
2	2	2	2	2	2	2	1	1	1	1	1	1.5

Comment: In retrospect, the quadriceps exercises should have been more intensive while the patient was wearing his casts. The present exercise program devotes especial attention to patients in casts, so that such severe atrophy is no longer encountered. After the cast has been removed, exercises should be increased gradually, to avoid any reactive effusion or soft-tissue induration. This patient is considered to have made an excellent recovery from such a severe injury. The results in this case refute the widely held opinion that surgical repair is essential in marked separation of the knee joint. Observation of many other equally good results after conservative treatment naturally raises the question as to whether the cures following operative treatment are not properly attributable to the postoperative immobilization, rather than to the surgical repair itself.

Case 2. As this parachutist jumped from the plane, the man in front of him momentarily "froze" in the doorway, causing the patient to trip and to tumble out headfirst, with poor body position. He became entangled in the suspension lines and wrenched his left knee during the opening shock. Examination disclosed a rupture of the tibial collateral ligament, which allowed 15 degrees of abduction of the knee without anaesthesia. The knee was extremely tender at the femoral insertion of the tibial collateral ligament, and weight-bearing was impossible. His left boot showed a definite brush burn, similar to that shown in Figure 2.

The sectional toe-to-groin cast was applied, which held the knee in semiflexion and in the varus position. The cast was replaced in two weeks by a walking cylinder, which was removed seven weeks after the injury.

At the end of *three months* there was mild residual instability, amounting to 3 degrees of abduction in semiflexion, and slight anterior hypermobility. The joint was quite stable in extension. The patient stated that his knee still was weak and tended to buckle. Atrophy amounted to one and one-quarter inches. About 15 degrees of limitation of flexion was observed. The patient cooperated well in performing the prescribed exercises.

Five months after injury the patient showed a very good symptomatic result and had no difficulty with his knee, except that it ached in rainy weather. He walked seven miles without any trouble, and sprinted 300 yards in forty-seven seconds. Objectively, the stability was unchanged. There was no quadriceps atrophy. The patient cooperated energetically in the prescribed exercises, and had been working as a physical instructor on the Reconditioning Service.

At the end of *seven months,* this soldier had no complaints whatever. He was able to march twelve miles in military formation without pain, ran as well as ever, played baseball, shoveled dirt without pain, and performed strenuous field duties at the Infantry School. Except for the slight residual instability previously noted, his knee and thigh were clinically normal. His disability rating was 1.2. The patient returned to full military duty at his own request.

Comment: This is one of the best functional results obtained in the entire series. It substantiates the fact that a minor degree of residual instability is not in itself disabling, or even productive of symptoms; and hence cannot be used as the sole criterion of recovery. The only rational basis for evaluating a knee is in terms of its functional capacity.

* The average of the individual quantitative ratings furnishes a useful disability rating of the knee as a whole.

Abduction Injury with Poor Result

CASE 3. This parachutist's left knee was abducted violently by the suspension lines during the opening shock, and again when he struck the ground. Despite severe pain in the knee, he limped about with a cane and was treated for five days at his organization with physiotherapy and sleeping tablets. He finally had to be hospitalized because of persistent pain, as well as an alarming ecchymosis of the knee and leg. On admission, the diagnosis was tear of the tibial collateral ligament of the left knee, with possible injury to the fibular collateral ligament. Roentgenograms were negative. No clinical details were recorded as to the degree or direction of the instability.

The following information was abstracted from his clinical record: The patient was immobilized in the toe-to-groin cast (one stage) for six weeks. After the cast had been removed, swelling and oedema quickly developed, and a walking cylinder was applied for an additional three weeks.

Recovery was slow and unsatisfactory. When he came under the observation of the authors (four months after injury), he showed a persistent effusion that fluctuated with the amount of physical activity, but never entirely disappeared. Analysis of the fluid was as follows:

Volume:	30 cubic centimeters	
Character:	Turbid yellow, with fibrinous flecks	
Total protein:	330 milligrams per 100 cubic centimeters	
Blood-cell count:	White blood cells	288
	Polymorphonuclear neutrophils	10 per cent.
	Lymphocytes	90 per cent.

Bacteriological examination showed no organisms on smear or culture. The fluid re-accumulated promptly after aspiration. Flexion was limited to 120 degrees. Atrophy of the thigh was one and one-half inches. The patient complained of recurrent dull pain after exercise, and a definite sense of instability, even while walking. Objectively, he showed thirteen millimeters of sagittal instability and 4 degrees of residual abduction instability. With the knee in full recurvatum position, however, this instability was not evident. Both knees displayed 10 degrees of recurvatum laxity. The patient mentioned that, unless he locked his knee in hyperextension, it tended to "slip sideways" on walking, and he had to concentrate on his footing.

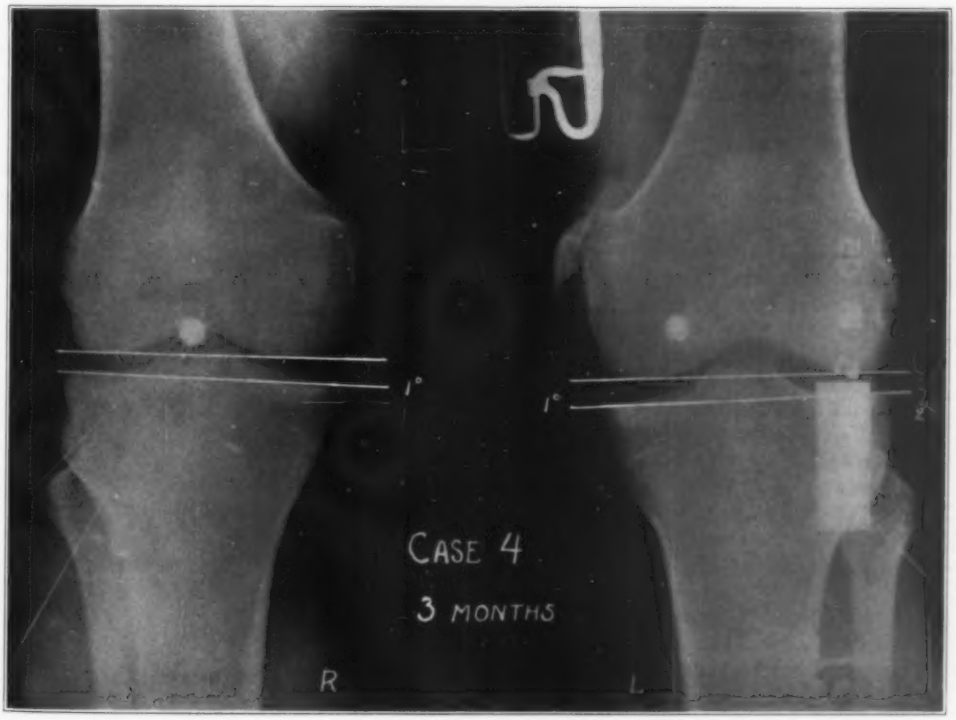

FIG. 6

Case 4. Very slight residual instability followed a severe abduction injury. Note the pronounced calcification of the tibial collateral ligament, still in the "evolutive" stage.

Five months after the original injury, the patient stepped into a rut, twisted his left knee again and suffered a recurrence of pain and swelling that lasted for ten days.

At the end of *six months*, the knee still was weak and symptoms persisted. The patient could walk three miles and could trot short distances, but was unable to engage in active sports, such as tennis or volleyball, because sudden pivoting aggravated the swelling and caused the knee to ache all night. He also complained of painful clicking and of a tendency for the knee to buckle and slip, particularly on uneven ground. Objectively, the instability remained as described previously. Flexion was limited to 135 degrees. Atrophy of the thigh was one and one-quarter inches. The chronic effusion persisted. The patient cooperated poorly in the quadriceps exercises and frequently became depressed and irritable. His disability rating was 2.8.

Comment: The result in this case is probably the worst of the entire series, and illustrates several technical errors in diagnosis and treatment:

1. The serious nature of the injury was not appreciated at the initial examination, and consequently the patient was allowed to limp around for five days without immobilization. The authors have noted repeatedly that a delay of more than twenty-four hours in starting immobilization definitely prejudices the final result.

2. Immobilization was unsatisfactory. In such a serious injury, immobilization should have been continuous for ten weeks. Furthermore, it is technically awkward to support a painful, unstable knee in accurate alignment while applying the toe-to-groin cast in one stage. Sectional casts are strongly recommended.

3. Quadriceps exercises were not pursued systematically, largely because of lack of cooperation on the part of the patient. The resulting deterioration of the thigh muscles was an important factor in his poor endurance and agility.

4. A final factor contributing to poor stability was the amount of laxity of the normal knee. Patients who normally show appreciable genu recurvatum do not recover so well as those whose joint structures are congenitally more stable.

Severe Abduction Injury with Calcification of Tibial Collateral Ligament

CASE 4. This parachutist somersaulted forward upon leaving the plane, caught his left foot in the suspension lines, and wrenched his left knee during the opening shock. He was treated in his quarters for a day, with the diagnosis of acute traumatic effusion; but pain in his knee kept him awake all night and finally necessitated hospitalization. Examination on admission revealed generalized oedema about the knee and the medial aspect of the thigh and extreme instability of the tibial collateral ligament, which allowed at least 20 degrees of abduction without anaesthesia. "Surgical repair imperative" was the opinion of the admitting surgeon.

The patient was immobilized in the sectional toe-to-groin cast and later in a cylinder, which held the knee in varus correction for a total of six weeks. He was also fitted with a medial wedged heel. When the cast had been removed he showed good stability, but marked suprapatellar induration and stiffness of the knee were present.

Eleven weeks after injury the patient was very active physically; he played volleyball daily, although this exercise caused local warmth and transient swelling. There was still considerable suprapatellar induration, and return of motion was delayed. Range of flexion was from 10 degrees to 110 degrees. Atrophy was two and one-eighth inches, as compared with the opposite thigh. Except for a trace of abduction instability in semiflexion and slight anterior drawer action, the knee was quite stable. The patient cooperated well in performing the exercises.

At the end of *five months* there was rapid symptomatic improvement, which had been observed especially during the previous month. His only symptom was pain over the medial aspect of the knee on forced flexion. He could walk from five to ten miles, ran well, and was in considerable demand as a volleyball player. Moreover, in spite of a medical recommendation for a limited-duty assignment, he pleaded his way back to his former organization and had made three additional parachute jumps since leaving the hospital. Objectively, he still showed slight swelling, induration, and tenderness over the medial femoral condyle. Range of flexion was from 3 degrees to 130 degrees. There was atrophy of one inch. His gait was normal, both when walking and running. Stability was unchanged (Fig. 6). The disability rating was 1.5.

Six months after the injury a report was received from the Battalion Surgeon at the patient's new post. An extract from this report follows:

"Stability normal. . . . No abnormal abduction. . . . About 15 per cent. limitation of flexion. . . . Thigh measurements equal. . . . Slight joint enlargement of medial aspect of knee; no joint effusion. . . . Functional capacity is not yet normal, endurance is good, agility is fair. . . ."

Comment: Although surgical repair was initially recommended for this patient, he has had a very good result from the program of conservative immobilization. He shows the most pronounced picture of calcification about the tibial collateral ligament; but, aside from persistent local tenderness and limitation of flexion, this has not been associated with much clinical disability.

Abduction Injury with Delayed Quadriceps Recovery

CASE 5. A soldier injured his left knee in the opening shock of a parachute jump, when he somersaulted forward on leaving the airplane. After landing, he had severe pain along the medial aspect of the left lower extremity and was unable to walk. Upon admission to the hospital, he showed brush burns, not only on his boot, but also along the entire medial aspect of the left knee and left leg. He displayed severe abduction and anteroposterior instability of the knee, but the exact degree was not recorded. There was pain on any attempted motion, and tenderness over both tibial and fibular collateral ligaments. The routine roentgenograms, without special positioning, showed no abnormality of the knee except soft-tissue swelling.

The patient was immobilized in the sectional toe-to-groin cast for four weeks. At the end of this time, another toe-to-groin cast was applied without padding, holding the limb in nearly full extension. Immobilization was discontinued six weeks after injury, and physiotherapy and graduated activity were started.

Four months after the injury the patient still had severe symptoms; he limped on the toes of his left foot and showed about 5 degrees of limitation of extension. Flexion was possible to 120 degrees. There was one and one-quarter inches of atrophy of the left thigh. He was able to walk about two miles on pavement, but could not run; the knee swelled whenever he attempted to walk on uneven ground. Objective stability was good; there was only about 2 degrees of abduction instability in semiflexion, and slight anterior hypermobility.

After *six months* his condition was much the same, except that the swelling and limp had practically disappeared. The patient admitted having neglected all exercises. Atrophy was one and three-

FIG. 7-A

FIG. 7-B

This patient (Case 6) had extreme "adduction-plus-recurvatum" instability. The conventional roentgenograms in this case, without special positioning, showed no abnormality except soft-tissue swelling.

quarters inches. Flexion had improved to 135 degrees, but the knee remained weak and painful and felt unsteady on uneven ground. He got considerable relief from the medial heel wedge.

At the end of *eight months* the knee was improving slowly, but disability was still present. The knee ached at night after any exercise, such as carrying a suitcase for fifty yards. The patient's duties were largely sedentary, and the quadriceps exercises were being neglected. There was atrophy of one and one-eighth inches. There was no longer any swelling.

An examination at the end of *ten months* revealed that subjective improvement in the previous two months had been negligible. The patient had been taking no exercise at all, in spite of repeated urging. Atrophy had increased to one and one-quarter inches. Stability of the ligaments, however, was very good. The joint was completely stable in extension and showed only slight residual abduction in semiflexion. Anterior hypermobility was minimum. The persistent symptoms seemed disproportionate to the objective findings, which, except for the quadriceps atrophy, indicated an excellent result. Accordingly, the patient was returned to the hospital so that quadriceps exercises could be carried out under the supervision of the Reconditioning Service. His disability rating was 2.1.

At *eleven months,* after one month of supervised exercises, atrophy of the thigh had decreased to agility. The patient could walk over five miles and could trot half a mile; but he was unable to run rapidly without a limp. The continuous ache in the knee had subsided completely. He could walk ten miles without favoring the limb, and his only symptom was a slight pain beneath the patella when he ran on uneven ground. The patient was very much pleased with his recovery, and had enlisted for a term in the Regular Army. His disability rating was 1.4.

Comment: This case illustrates the parallel between clinical disability and quadriceps atrophy. It has been noted repeatedly that, when quadriceps exercises are neglected, the clinical improvement ceases. It should be mentioned that ordinary walking is not considered quadriceps exercise; neither is passive physiotherapy.

Adduction Injury with Recurvatum

CASE 6. A parachutist's right knee collapsed when he struck the ground violently, upon landing from a jump. He was unable to walk, and was brought immediately to the hospital with a diagnosis of possible fracture of the right lower extremity. Examination disclosed marked soft-tissue swelling and tenderness over the lateral aspect of the right knee, with striking instability, so that the limb could be adducted 30 degrees without undue pain. There was also a recurvatum instability amounting to 30 degrees. No abduction instability was noted (Figs. 7-A and 7-B).

The right lower extremity was immobilized in the sectional toe-to-groin cast for four weeks, with the knee in semiflexion and valgus correction; then a walking cylinder was applied and maintained for an additional four weeks, with the knee in nearly full extension. Upon removal of the cast, there remained moderate adduction instability, but no recurvatum. It was felt that the patient had regained maximum stability, and immobilization was accordingly discontinued. There was atrophy of one and one-half inches. Intensive exercises of the limb were started.

At the end of *three months* he walked without a limp and ran well for short distances, in spite of moderate residual adduction instability. There was still a tendency for the knee to swell after exercise. The range of motion was good; the patient could extend his knee completely and could flex it to 140 degrees. There was one and one-eighth inches of atrophy of the thigh.

Four months after injury the adduction instability measured 9 degrees by roentgenogram, but the patient had remarkably little subjective disability. His knee occasionally felt "loose" on twisting, but he could hike ten miles and could run 300 yards in forty-six seconds. He played a good deal of baseball and engaged in other sports. The knee showed no swelling or induration, and flexion had increased to 150 degrees. There was atrophy of three-quarters of an inch.

At the end of *six months* there was continued improvement. The patient claimed that his knee was stronger and steadier, although objectively the residual instability was unchanged. The range of motion was normal. There was atrophy of one-half inch. His only complaint was minor aching in inclement weather. The patient was pleased with the result and was quite active physically. His disability rating was 1.6.

Comment: Because of the considerable residual instability in this case, surgical repair of the fibular collateral ligament was considered after the cast had been removed; but the patient's functional improvement was so rapid, and the final disability so slight, that the operative procedure did not seem justified. Only three cases of adduction injury were encountered, but none of these patients seemed to be handicapped by the residual instability. As mentioned earlier, this is probably due to active muscle support of the tensor fasciae latae, which offers direct anatomical reinforcement for the injured ligament.

Complete Anterior Dislocation of the Knee

CASE 7. A parachutist landed in a ditch at night, dislocating his left knee. He was brought to the hospital in a Thomas splint, and showed clinical and roentgenographic findings of a complete anterior dislocation of the tibia. No circulatory or neurological abnormalities were observed.

The dislocation was reduced easily under pentothal anaesthesia, and the knee was immobilized in a padded toe-to-groin cast. This became loose after three weeks and was changed for a skin-tight toe-to-groin cast, which held the knee in almost full extension. Five weeks later the cast was removed; good stability was revealed, but there was pronounced stiffness and suprapatellar induration. After a trial of graduated activity, the induration showed no improvement; and the patient was returned to a walking cylinder for an additional three weeks. All immobilization was discontinued twelve weeks after injury.

Fourteen weeks after injury the patient still limped noticeably. The most striking clinical features were the persistent induration of the soft tissues about the front of the knee, and the limitation of flexion to 85 degrees. Stability was good; there was only slight abduction in semiflexion and slight anterior hypermobility. There was atrophy of one and one-eighth inches. The patient received graduated quadriceps exercises.

At the end of *four months* he could walk five miles and could trot a little. The knee tended to swell on excessive activity, but the induration was subsiding gradually. Flexion had improved to 100 degrees, and atrophy had decreased to three-quarters of an inch.

Five months after the injury the knee seemed stronger, and the patient could stand all day with minimum discomfort. Flexion was limited to 120 degrees, which prevented him from running normally. The residual instability remained as before, except that he now displayed a few degrees of recurvatum in the injured knee. There was atrophy of one-quarter inch.

Examination at the end of *six months* revealed continued improvement in strength, endurance, and agility. The patient could walk over five miles and could trot half a mile; but he was unable to run smoothly, because flexion was still limited to 120 degrees. He could run up and down stairs, two or three at a time. Excessive activity still provoked mild transient effusion. Roentgenograms disclosed Pellegrini-Stieda type of calcification near the medial femoral condyle. There was no change in stability. The thigh measurements were equal. The patient was taking long, cross-country bicycle rides to complete his rehabilitation. Disability rating was 1.7.

Comment: According to widely accepted indications, the more severe the injury, the more imperative is surgical repair. In view of the present clinical experience, however, this reasoning does not appear valid. Since conservative treatment yielded such good results in complete dislocation and in the extreme lateral instability illustrated by Case 1, there is ample justification for conservatism in the less severe injuries.

SUMMARY

1. Eighty-five cases of acute instability of the ligaments of the knee were treated by conservative immobilization.

2. Most of the patients were parachutists, who tore the tibial collateral ligament of the left knee during the opening-shock phase of the parachute jump.

3. The plan of treatment consists in immobilization in plaster-of-Paris, supplemented with intensive exercises for the thigh musculature.

4. End results are evaluated on the basis of the functional capacity of the knee, according to specific clinical criteria.

5. The most reliable single index of disability is the amount of quadriceps atrophy. Rehabilitation of the shrunken quadriceps invariably improves the functional capacity of the knee.

6. Recovery of stability has been very satisfactory. Ninety-five per cent. of the abduction injuries heal with less than 5 degrees of residual instability.

7. Calcification of the tibial collateral ligament is a frequent complication, but has not proved disabling.

8. Recovery of flexion and extension has been excellent.

9. Conservative immobilization has yielded excellent results in this series.

NOTE: This study was carried out under the supervision of Major Roy Ciccone, M.C., Chief of the Orthopaedic Section, Army Service Forces Regional Hospital, Fort Benning, Georgia, and the authors

wish to express their gratitude for his generous advice and assistance. Appreciation is also extended to the members of the X-Ray Department for their splendid cooperation. The mechanism of the opening-shock injury was illustrated by the Training Aids Section of The Parachute School, and the illustrations were reproduced by the Army Field Printing Plant and the Signal Corps Laboratory at Fort Benning.

REFERENCES

1. Abbott, L. C.; Saunders, J. B. deC. M.; Bost, F. C.; and Anderson, C. E.: Injuries to the Ligaments of the Knee Joint. J. Bone and Joint Surg., **26**: 503–521, July 1944.
2. Böhler, L.: The Treatment of Fractures, Fourth English Ed., Translated by E. W. Hey Groves. Baltimore, William Wood and Co., 1935.
3. Brantigan, O. C., and Voshell, A. F.: The Mechanics of the Ligaments and Menisci of the Knee Joint. J. Bone and Joint Surg., **23**: 44–66, Jan. 1941.
4. Brantigan, O. C., and Voshell, A. F.: The Tibial Collateral Ligament: Its Function, Its Bursae and Its Relation to the Medial Meniscus. J. Bone and Joint Surg., **25**: 121–131, Jan. 1943.
5. DeLorme, T. L.: Restoration of Muscle Power by Heavy-Resistance Exercises. J. Bone and Joint Surg., **27**: 645–667, Oct. 1945.
6. Kulowski, J.: Post-Traumatic Para-Articular Ossification of the Knee Joint (Pellegrini-Stieda's Disease). Am. J. Roentgenol., **47**: 392–404, 1942.
7. Lord, C. D., and Coutts, J. W.: A Study of Typical Parachute Injuries Occurring in Two Hundred and Fifty Thousand Jumps at The Parachute School. J. Bone and Joint Surg., **26**: 547–557, July 1944.
8. Palmer, I.: On the Injuries to the Ligaments of the Knee Joint. A Clinical Study. Acta Chir. Scandinavica, **81**: Supplementum 53, Stockholm, 1938.
9. Peterson, L. T.: The Quadriceps. *In* Lectures on Reconstruction Surgery of the Extremities, The American Academy of Orthopaedic Surgeons, p. 391. Ann Arbor, Michigan, Edwards Brothers, Inc., 1944.
10. Ritvo, M., and Resnik, J.: Pellegrini-Stieda's Disease (Post-Traumatic Calcification of the Collateral Tibial Ligament of the Knee). Am. J. Roentgenol., **32**: 189–195, 1934.
11. Sayre, Edwin B.: Personal communication.
12. Terhune, S. R.; Eddleman, T. S.; Thompson, S. B.; and Read, B. S.: The Care of the Knee Following Excision of a Meniscus. J. Bone and Joint Surg., **25**: 663–669, July 1943.
13. Tobin, W. J.; Ciccone, R.; Vandover, J. T.; and Wohl, C. S.: Parachute Injuries. Army Med. Bull., No. 66, pp. 202–221, Apr. 1943.
14. West, F. E.: Diagnosis and Treatment of Internal Derangements of the Knee. Surg. Clin. North America, **25**: 111–135, 1945.

DISABILITY EVALUATION FOR THE HAND *

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The fundamental premise of this paper is that appraisal of disability should be based upon function. The present systems of disability evaluation have evolved over a period of several years as a joint endeavor of the physician and the agency giving compensation. Through the efforts of such men as McBride, Kessler, and others, accurate and concrete tables have been formulated to cover a variety of conditions in the hand. For the case which duplicates the conditions found in the tables, their figures are adequate and workable. More complex problems, however, can be judged only by the most experienced observer. The novice or the moderately trained physician frequently finds himself lost in a maze of detail when studying these empirical formulae, and often his conclusion is the result of guesswork. The purpose of the present discussion is to present a simplified method of disability evaluation, based upon function, which incorporates the time-tested values set forth in the past.

Disability evaluation has a dual purpose: The first is its traditional use in the appraisal of an end result of trauma or disease for an insurance company or an industrial-accident commission. The second—and herein lies the most important medical obligation—is the determination of disability as a basis for planning treatment. In order to establish clear indications for prognosis, the physician must know what the present status of the hand is and what the result of treatment will be within the realm of reasonable expectancy. This will enable him to judge how worth-while the procedure is in view of the degree of improvement expected, the seriousness of the procedure, the time involved, and the economic status of the patient.

In this paper the authors are concerned with the hand alone; the remainder of the upper extremity is not considered. The three fundamental units of function in the hand itself are grasp, pinch, and hook.[3] These actions are fundamental, because they contain all the elements of power, motion, and dexterity used in any of the lesser activities of the hand. In the following discussion, certain values have been established arbitrarily for these functions on the basis of their relative importance. This has been necessary, since no precedent exists for formulating these values. They have simply been set down by the authors as their opinion of the relative importance of each function and may, of course, be changed with greater knowledge in the future.

Grasp may be defined as the combined action of the fingers against the opposed thumb and the palm of the hand. Its greatest use is in the last half of this motion, as grip is consummated. It is worth 50 per cent. of the value of the hand. Pinch is the apposition of the pad of the thumb against the pads of the opposing fingers. This is worth 30 per cent. of the value of the hand. Hook is simply what the word implies: The fingers are flexed so that their pads lie parallel and slightly away from the palm, forming a hook. This is worth 20 per cent. of the value of the hand. The modification of these values by sensory changes is explained in a later section.

The system of disability evaluation presented here is embodied in the chart shown as Figure 1. Certain radical changes from the standard methods will be noted:

1. All figures presented are in terms of the three primary functions of the hand: grasp, pinch, and hook.

2. The value given the little finger has been increased over that given the ring finger, because of its more strategic location in the hand. This polar position adds to the breadth and stability of the hand in grasp and hook.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

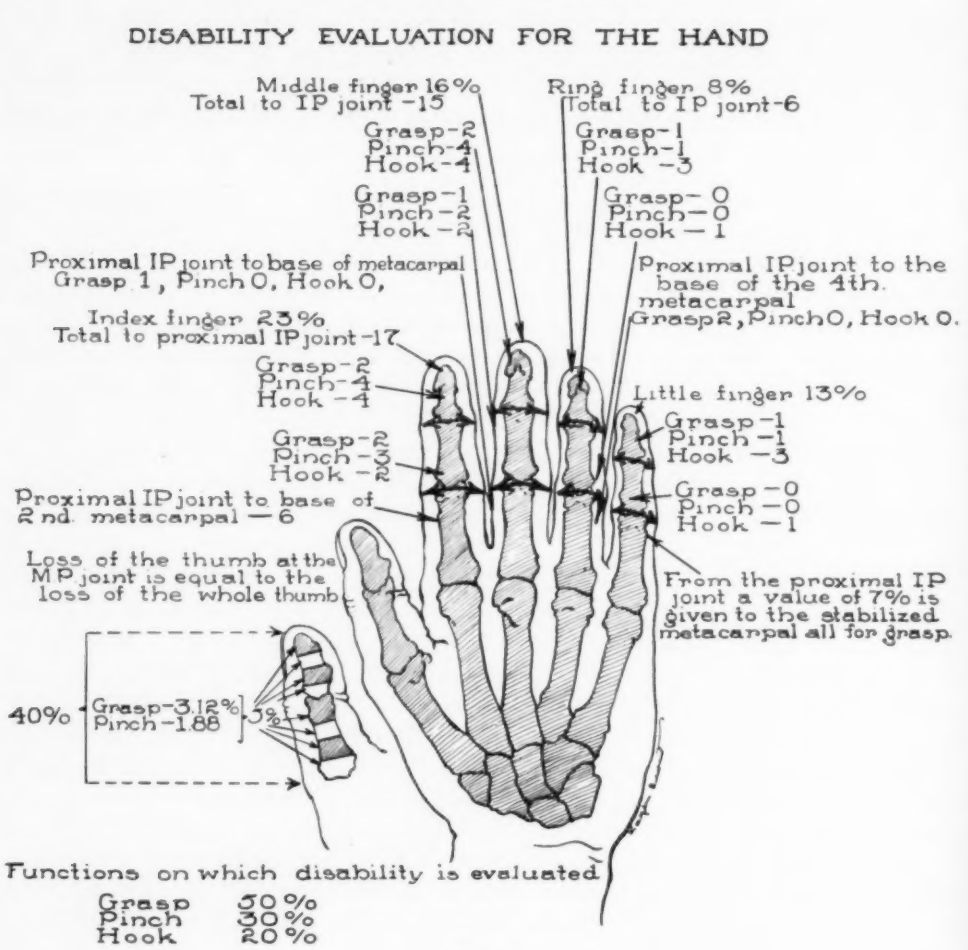

FIG. 1

3. Between the proximal interphalangeal joint of any one finger and the carpometacarpal articulation of that finger, any loss is given the same value.

The last statement demands some elaboration. In each finger, a different situation exists when there is an amputation above the proximal interphalangeal joint. For instance, amputation through the proximal phalanx of the index finger leaves a hand that still grasps well, in that the palm still forms a wide base against which the remaining fingers and thumb may clasp an object. This is a hand which, in many instances, may be perfectly satisfactory; but, on the other hand, the stump may impede the web and may also interfere with pinch, which is now carried out by the middle finger. If the metacarpal of the index finger is resected through its base, or if it is disarticulated, the web is left unhampered, so that pinch action may take place freely, and the appearance is improved. However, the stability of the grasp is diminished, due to the narrowing of the palm. In the middle finger and in the ring finger, amputation through the proximal phalanx leaves an unsightly hand with a space between the fingers during grasp. This is a decided handicap when small objects, such as a handful of nuts or beans, are to be picked up and held in the cupped hand. Grasp of larger objects, nevertheless, remains good. If the metacarpal is resected in one of these two fingers, the appearance is improved and the gap in grasp is closed; but a narrow and less stable hand results. When the little finger is amputated through the proximal phalanx, there remains adequate breadth for grasp and cupping, depending upon the mobility of the metacarpal. Some patients prefer amputation through

the metacarpal, however, because the appearance is improved and because this eliminates catching of the stump during such activities as reaching into their pockets.

It may be seen, therefore, that the degree of loss above the proximal interphalangeal joint does not alter the percentage of functional disability for all types of work. The improvement of one function is counterbalanced by the loss of another.

CHART OF DISABILITY EVALUATION

In the lower left corner of the chart (Fig. 1) are found the values for grasp, pinch, and hook. These are set arbitrarily at 50 per cent., 30 per cent., and 20 per cent., respectively. Above is the thumb, which is valued at 40 per cent. Since the thumb is one of the two major poles in grasp and pinch, this value was determined simply by taking one-half of the value of grasp (25 per cent.) plus one-half of the value of pinch (15 per cent.). The thumb is considered as a unit of function only from the tip to the metacarpophalangeal joint; proximal to this, all ability to grasp and pinch disappears. The inset drawing of the thumb demonstrates the values in amputation. Since the thumb is valued at 40 per cent., each quarter phalanx is valued at 5 per cent. Associated lesions, such as deformed nails, neuromata, painful cicatrices, *et cetera*, are evaluated by determining the extent to which they interfere with each of the major functions. An arrow pointing to the top of each finger indicates the value of that finger in terms of percentage of the hand as a whole. The distal interphalangeal joints are indicated by interrupted black lines. Solid black lines indicate the location of the proximal interphalangeal joints. Beside each phalanx, the percentile values of grasp, pinch, and hook are given, according to the importance of each of these elements. Below this is given the value from the proximal interphalangeal joint to the base of the metacarpal. One value is set for any loss in this region, when only a single finger is involved.

Use of Chart

In amputations, the following principles are used: In amputation of a single finger, the percentages of grasp, pinch, and hook of each phalanx are added to give the value of disability. If only a portion of the finger is lost, this value is apportioned to the nearest quarter of a phalanx. In amputations which include the proximal interphalangeal joint, the total value of the finger is used, regardless of whether the amputation is in the phalanx or in the metacarpal. In multiple finger amputations, the total is made up of the values for each phalanx lost. When the metacarpals for more than one finger have been amputated, however, the appraisal is made on the basis of the major function of the whole hand, as listed in the lower left corner of the chart.

Amputation of the thumb has already been described.

Lesions of the palm and the thenar eminence, and multiple involvement of the long tendons and their motors, are evaluated on the basis of alterations in the major functions of grasp, pinch, and hook. In instances other than amputation, the loss is judged according to the limitation in grasp, pinch, and hook which occurs in each finger.

Pain is evaluated according to the extent to which it interferes with each of the three major functions. Although pain is a subjective phenomenon, its results must be judged objectively. For example, an exquisitely tender neuroma in the pad of the thumb could eliminate all pinch in the hand (30 per cent.); affect grasp, through pain and awkwardness, so that the effective delivery of grasp would be only 10 per cent. instead of the normal 50 per cent.; and impair hook, due to loss of dexterity, so that its value would be only 15 per cent. instead of the normal 20 per cent. This would result in a residual value of the hand of 25 per cent. of normal.

Total loss of sensation is valued at 50 per cent. of the part. Thus a 50 per cent. loss of sensation would be valued as 25 per cent. disability of the part involved. In many in-

stances other disabilities are present, as well as loss of sensation. The rule in these cases is to determine in the usual manner the disability of the part on the basis of function. This is then the value of the disabled part. This figure is used to determine the value of the loss of sensation. For example, the middle finger is normally valued at 16 per cent. If the finger has been amputated in the mid-portion of the distal phalanx, the value of the disabled finger is 11 per cent. Associated nerve injury may have resulted in total loss of sensation in the remainder of the finger. Since sensation is valued as 50 per cent. of the part, there would be a further loss of 50 per cent. of 11 per cent., or 5.5 per cent.

In section of the median and ulnar nerves, and occasionally of the digital nerves, trophic disturbances may occur, which make the fingers or the hand useless, or partially useless, as far as function is concerned. Again in these instances, clinical judgment must be used in taking the major functions as a basis for evaluation.

REFERENCES

1. Kessler, H. H.: Accidental Injuries. The Medico-Legal Aspects of Workmen's Compensation and Public Liability, Ed. 2. Philadelphia, Lea and Febiger, 1941.
2. McBride, E. D.: Disability Evaluation. Principles of Treatment of Compensable Injuries, Ed. 3. Philadelphia, J. B. Lippincott Co., 1942.
3. Slocum, D. B., and Pratt, D. R.: The Principles of Amputations of the Fingers and Hand. J. Bone and Joint Surg., **26**: 535–546, July 1944.

DISCUSSION

Lieutenant Colonel Lot D. Howard, Medical Corps, Army of the United States: The whole problem of disability evaluation is a tremendous one, and one which most of us know very little about. We compile a few measurements, make a few general statements on paper, and then feel content, knowing that someone else will get out some tables and calculate a percentile figure.

As if our own peacetime industrial accident work is not enough of a headache, we are now confronted by thousands of partially disabled war veterans, who will need disability evaluation and who will be remunerated on this basis.

I had the opportunity of visiting a Veterans' Hospital on the way to this meeting, and observed the struggle they are having to establish temporary disability ratings for crippled hands, often with inadequate or incomplete records, and without the opportunity of examining the soldier.

Colonel Slocum's chart for the determination of disability in the hand appears workable, but has not had to meet the test of time as yet. It is not simple; but it cannot be, due to its very nature. Minor points may give rise to differences in opinion, but these may be adjusted to the individual case.

In dealing with the hand, one must not lose sight of the fact that the hand is, and functions as, a unit; thus, what a man can do physically with his hand under living and working conditions is what counts.

A rating on the basis of carefully planned performance tests under the observation of a physician should be ideal, but here the personal equation on the part of both the patient and the doctor would lead to gross error and inconsistency.

Yet, to break down the hand for analysis of the function of its separate parts, and to calculate multiple percentages of percentages, ending at times with a decimal point and two figures, would be comparable to an aborigine looking at a pile of bolts, nuts, wheels, and rods, and trying to visualize a moving jeep.

Men who are familiar with disability evaluation are the first to admit the difficulty in arriving at a fair and unbiased appraisal. Yet some standard must be set. All are agreed that an objective approach, such as has been outlined, must be used; yet the admission of this constitutes the first error in the appraisal, since the same limitations, objectively measured, need not necessarily give the same disability to different individuals, even in the same occupation.

Colonel Slocum's contribution is limited to the hand; yet he knows, as we know, that the usefulness of the hand is dependent also upon the function of the arm and shoulder for positioning and stability.

In thinking about disability evaluation in general, one cannot help but be impressed by certain aspects of the problems which have wide economic and sociological application, as the following examples indicate: How much is a hand worth? Is one man's hand worth as much as another man's hand? How much is a man's hand worth, if the man has no value from the standpoint of the group? Should a man in one state get more compensation for a given disability than a man in another state? Should a veteran

get the same as a man in industry? Just what are we compensating for, and who pays the bill? Such questions could go on indefinitely, and you cannot find an answer for any of them.

The problem persists and warrants serious thinking on the part of all medical men. Anyone undertaking such a difficult problem needs our encouragement; and criticism had best be reserved, unless something better can be offered.

I want to thank the authors for this opportunity to discuss their paper.

DR. EARL D. MCBRIDE, OKLAHOMA CITY, OKLAHOMA: I am pleased that someone is interested enough in the subject of disability to venture an essay on this program. Quite properly, Colonel Slocum has recognized "function" as the true basis of evaluating disability. Likewise, he points out that the functional reason for appraising the effect of disability on the body is to be able to judge the advisability of surgical procedures in terms of end results, and what they will mean toward loss or gain in function.

"Disability is a transformation of body structures, resulting in depreciation of normal ability to perform the functions of established physical accomplishments." Such a transformation may be the result of injury, disease, new growth, or malformation. The period of existence may be temporary, progressive, or permanent. It must be recognized that no two individuals develop function in the fingers, hands, or feet to exactly the same extent or proportion. Therefore, it is my opinion that any arbitrary assumptions of functional evaluation, such as Colonel Slocum has made—that the grasp of the hand is 50 per cent., the pinch 30 per cent., and the hook 20 per cent.—are not fundamentally sound. Actually, I think this is a very fair average assessment for each of the three functions. However, if we are to arrive at a uniform standard in evaluating disability, we cannot very well assume arbitrary values. We must, on the contrary, devise a dependable system, based on fundamental principles, as in other medical subjects.

How can we say that the function of grasp should have the same value of 50 per cent. for all hands? For instance, compare the hand of a laborer who digs ditches with the hand of one who has become skilled in using tools. I believe we might even say that the function of grasp would be rated somewhat higher in the hand of an orthopaedic surgeon than in the hand of a gynecologist, or of an eye, ear, nose, and throat surgeon.

It has been my contention that the fundamental factors which create function should be the basis of measuring function, rather than arbitrary divisions applied equally to any individual's hand.

What do I mean by fundamental divisions or factors of function? First, there is the factor of quickness of action, nimbleness, and speed of movement. Second, there is coordination of movement,—that is, the smoothness and the steadiness of action, or we might say the dexterity or the synchronizing of movements, which may have been cultivated over a lifetime and may even mean the difference between ordinary use of the hand and expert use of it. Third, there is the factor of strength. The lack of strength often creates a necessity for unusual effort or strain. Fourth, there is security of action,—that is, the confidence and dependence which one may have in the use of the part of the body. When a part of the body has been injured, there is a lack of trustworthiness and reliability, so that the part cannot be used without a certain amount of conscious effort. Fifth, there is the factor of endurance,—how long the individual can work with a disabled part.

Most individuals have to work for a living, and, if we were measuring the capacity of the disabled individual as to his ability to perform labor, we would add two other factors. One would be that of safety to himself and others as a workman, and the other would be the prestige of being found able-bodied in a pre-employment examination.

By applying any estimated percentile value to each functional factor within a total of 100 per cent., one can arrive at a very reasonable conclusion as to the related value of disabled parts of the body.

Returning to Colonel Slocum's scheme of disability of the hand, again I wish to commend him for his effort in this respect. I think his arbitrary divisions are very accurately conceived. Furthermore, I think his method is very easy for most of us to use. It is especially adaptable to the purpose for which he recommends it,—namely, that of evaluating disability as a basis for planning treatment.

No other part of the body requires such consideration as does the hand. It is unique that he has evaluated the little finger more than the ring finger. I believe he is perfectly correct in this observation. Colonel Slocum's scheme is especially adaptable for evaluation of the hand when amputations are considered. I believe it would be a little awkward to use it at times when various degrees of contractions and deformities are being considered for surgical improvement. His evaluations are placed chiefly on the location of various points on the individual phalanges.

From the standpoint of ankylosis and deformity, it is essential to base the elements of function upon joint action, more than upon bone deformity. Here, again, coordination, strength, endurance, and other factors must take precedence in the mind of the one who makes the evaluation of such a hand.

THE PROBLEM OF MENISCECTOMY IN THE SOLDIER

BY LIEUTENANT COLONEL W. ALEXANDER LAW

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Under Service conditions, injuries to the knee joint are as frequent as they are important; and they form a considerable source of sickness, with consequent hospitalization and loss of man power. A proportion of these injuries are meniscus lesions, and an attempt has been made in this series of cases to determine the value of operative treatment.

In a Base Hospital during the first six months of 1944, 120 "clean" knee-joint explorations were performed, and in 104 instances meniscectomy was carried out; of the remaining cases, missiles were removed from the joint in nine, loose bodies were removed in four, and nipping of enlarged infrapatellar pads of fat was found in three.

Careful selection of these cases was made in order to exclude those in which there were accompanying pathological changes,—such as osteo-arthritis, osteochondritis dissecans, undue laxity of collateral or cruciate ligaments, and gross wasting and weakness of the quadriceps muscle. These patients were regraded and treated by physiotherapy. The object of operation, therefore, was to keep the soldier in his category—usually that of the fighting man—and to enable him to return to full duties as rapidly as possible.

The problem is not quite the same as in civil life, where the patient requiring a meniscus operation is very frequently the athletic young man of good physique, with muscular development above the average. The British fighting soldier, although physically very fit, does not always have the muscle power of the first-class athlete; and yet, in the course of his training and actual fighting, he is subject to stresses and strains on the knee joint far in excess of those encountered in ordinary recreational activities. It is reasonable, therefore, to anticipate the necessity for a longer rehabilitation period in the case of the fighting soldier than in his civilian counterpart.

The initial injury occurred while the patient was playing football in fifty-six cases (54 per cent.); during military training or actual battle in twenty-three cases (22 per cent.); and as a simple accident, such as a fall or while kneeling at work, in twenty-five cases (24 per cent.). The strictly military causes included falls into bomb craters and diving for slit trenches (ten cases); jumping out of vehicles (three cases); blows from the starting handles of vehicles (four cases); parachute jumps (two cases); being caught and twisted in barbed wire (one case); and being blown over by blast (two cases). In one case a tiny missile had ripped the cartilage on its passage through the joint, and signs of internal derangement persisted until after meniscectomy, nine months later.

CLINICAL DATA

No patient in this series was submitted to operation unless it was clear that the disability was a real one and that the soldier was handicapped in performing his duties. The duration of history varied considerably, but all the patients had had recurrent attacks of instability and locking of the knee joint, alone or in combination; and the occurrence of at least an initial weight-bearing rotational strain on the flexed knee was always sought. This type of injury is indicative of a tear or detachment of the meniscus, as opposed to injury caused by abduction or adduction strain on the extended knee, which results in ligamentous damage.

Forty-four patients had a history of less than six months' duration; eighteen had a history lasting from six to twelve months; eighteen had a history lasting from one to two years; and twenty-four had a history of over two years' duration. The incidence of injury to the right and left knee was about equal,—fifty-three and fifty-one instances, respectively.

The medial meniscus was the site of the lesion in eighty-nine cases, and the lateral meniscus in only fifteen cases. One reason for this disparity is that the majority of patients with lesions of the lateral meniscus were not subjected to operation. This applied particularly to cases of cystic degeneration, where recovery is frequently prolonged and incomplete, so that downward grading is necessary. Therefore it is more satisfactory from the point of view of conserving both man power and hospital accommodations to reclassify these cases without operation. For similar reasons, patients with lesions of both menisci were not considered suitable for operative treatment.

Effusion and joint locking were rarely seen in these cases, both having resolved or been treated during evacuation to the Base Hospital, but McMurray's test was found particularly useful; the presence of an audible and palpable "thud" and the degree of knee extension at which this occurs not only confirmed the diagnosis but indicated the site of the tear in the meniscus. In some cases this entailed the use of diagnostic manipulation under pentothal anaesthesia.

Roentgenography was considered essential to exclude the possibility of loose and foreign bodies, missiles, or osteo-arthritic changes in the joint.

In a few cases where the degree of disability was in doubt, provocative physiotherapy was employed and careful observation was kept for the recurrence of pain, joint swelling, and locking. In all cases preoperative physiotherapy was used, not only to restore power and tone to the quadriceps muscle, but also to teach the patient the exercises necessary for him to perform after operation. The physiotherapist, too, was able to study the patient and gain his confidence,—both important adjuncts to rapid convalescence and rehabilitation.

OPERATIVE DETAILS

A complete skin preparation for forty-eight hours with flavine, an operative field rendered bloodless by applying an Esmarch bandage, and a non-touch technique were invariably employed. A horizontal incision, about one and one-half inches long, was made in the line of the joint. This incision extended from the region of the anterior horn of the meniscus to near the anterior border of the fibular collateral ligament; the ligament was always carefully avoided, although it could be inspected, if desired.

The whole meniscus was invariably removed. It has been stated that such a procedure injures the joint excessively and is not necessary. However, with the approach described, suitable narrow deep-bladed retractors, and a sharp meniscectomy knife, the trauma to the knee joint in freeing the whole cartilage is minimum, and unexpected lesions of the posterior horn are not missed. Tears of the posterior horn, either alone or in conjunction with other lesions, were found on nineteen occasions (18 per cent.) in this series, and double bucket-handle tears were discovered in three additional cases,—strong enough indication for total meniscectomy. In two cases a loose posterior horn, which remained after a previous operation elsewhere, was removed through a vertical incision behind the posterior margin of the tibial collateral ligament. That there was no undue trauma in these cases is also borne out by the fact that there was not one instance of postoperative effusion in the knee joint severe enough to require any relaxation of the knee bandage, far less aspiration of fluid from the knee joint.

After closure of the wound in layers, a firm dressing was applied and no back splint was used. The Esmarch bandage was removed after the knee bandages had been applied. Postoperative observation was made to exclude oedema from too tight bandaging and foot drop from pressure on the peroneal nerve at the neck of the fibula.

Quadriceps-contraction exercises were commenced the day after operation and continued daily, together with attempts at straight-leg raising and exercises with the leg partially supported. The dressing was untouched until the skin sutures were removed, on the tenth day; flexion exercises were commenced on the fourteenth day, when the patient was

allowed out of bed, wearing a crepe bandage. It is considered that, by confining the patien to bed for this period and avoiding knee flexion, sound healing of the suture line wa encouraged; and that the bed exercises did not interfere with this healing, but were essen tial to maintain good tone and power of the quadriceps muscle.

From the second week onward, treatment consisted of a graduated course of physio therapy, carried out primarily in the Hospital and finally at a Convalescent Depot. Thi consisted of static quadriceps exercises and the use of weights and pulleys to provid resistive exercises; and gradually advanced to remedial and general exercises, therapeuti games, and physical training. Massage and faradism were rarely employed, and then onl in patients who were slow to develop ability to contract the quadriceps voluntarily. Suc treatment was supplemented, and replaced as soon as possible, by active exercises. Th interest and active cooperation of the patients are essential for speedy rehabilitation which can be encouraged and maintained by grouping these patients in special wards an classes, thus developing a competitive spirit.

THE CARTILAGE LESION

The main types of injury found in the eighty-nine cases of medial meniscectomy ca be grouped as follows:

	Number	*Per Cent.*
Bucket-handle tears	55	61.8
Peripheral detachment	12	13.5
Tears of posterior horn	13	14.6
Pedunculated fragments and tears of anterior horn	8	9.0
Cystic changes	1	1.1

This grouping, applied to the fifteen cases of lateral meniscectomy, is as follows:

Bucket-handle tears	4	26.7
Tears of posterior horn	1	6.7
Pedunculated fragments and tears of anterior horn	5	33.3
Cystic changes	5	33.3

The percentage incidence here is of little significance, as these cases were even more care fully selected for operative treatment.

Correlation of the initial accident with the type of meniscal lesion disclosed that foot ball injuries produced the bucket-handle tear in both medial and lateral menisci, and that cystic changes in the lateral meniscus might be related to a blow in that region; but more frequently the patient could remember no real injury, the onset of the disability being insidious.

In a considerable number of the cases a large protuberant infrapatellar fatty pad was seen at operation, in addition to the cartilage lesion. When this pad showed signs of being nipped between the bone ends, with resultant bruising, hemorrhages, or the formation of fibrofatty tags or polyps, partial excision was performed. No ill effects were noted from this procedure in ten cases, although it might be expected that this additional intra-articu lar trauma would tend to increase postoperative effusion, or even result in hemarthrosis.

Less than half (five) of the posterior-horn lesions were attributable to football in juries. The majority resulted from a fall while traversing rough ground, either during training or in actual battle; but the character of the knee strain was similar to that in curred during a football injury and consisted of rotation on the flexed knee, the foot being supported and taking the body weight.

Where the lateral meniscus was torn or detached, a football injury was the initial cause in eight of the ten cases. No definite injury could be determined in the five cases of cystic change. One patient with cystic change in the anterior horn of the medial meniscus gave a history of an initial twist of the knee at football, six months before, followed by frequent recurrences of pain, swelling, and locking.

Evidence of osteo-arthritic changes in the knee joint was seen at operation on four occasions. Three of these patients had histories of longer than two years' duration and were regraded before completing convalescence, but the fourth patient retained good function and an A category.

Osteochondritis dissecans was noted at operation in three other cases, and, although recovery was normal, reclassification was carried out; the joint was regarded as unsuitable for severe stress and strain.

The occurrence of a bursa around the lateral head of the gastrocnemius was noted in two cases, but subsided in the course of physiotherapeutic treatment and appeared to leave no ill effects.

In one patient thrombophlebitis developed in the calf, and this necessitated longer convalescence and downward grading.

RESULTS OF TREATMENT

The average time spent in the Hospital after operation for all the patients in this series was thirty-four days. In the fourteen patients who completed their treatment in the Hospital and did not go to the Convalescent Depot, the average time taken in returning to duty was forty-five days.

The length of the history of disability—whether less than six months or over two years—made no appreciable difference in this postoperative recovery rate, but frequently patients with a longer history required a longer course of preoperative physiotherapy and therefore a longer total period in the Hospital. An average figure for total hospital stay would not be pertinent in this series, as in many instances several weeks were spent in evacuation, with little or no preoperative treatment. The cases of cystic lateral meniscus had a slower recovery rate, requiring on an average forty-five days in the Hospital before final rehabilitation.

No ill effects from the horizontal incision were noted or reported from the later follow-up. A few patients had anaesthesia and numbness in the infrapatellar region shortly after operation, but all signs of this had disappeared in from six to twelve weeks and no neuroma was reported to have developed. There was no case of wound or joint infection.

The power of full flexion of the knee had returned in nearly all the cases within from twenty-one to twenty-eight days, but the length of final rehabilitation was in direct proportion to the degree of wasting and weakness of the quadriceps muscle. The average time taken to attain fitness for duty, including treatment at a Convalescent Depot, was fifty-four days. Making allowances for time spent at Training Depot or Reinforcement Center, the total period of absence from duty in the forward area would amount to approximately eighty days. The standard of fitness required for return to duty was a knee joint free from pain, swelling, or undue laxity, with full quadriceps power and full range of flexion and extension. In addition, the confidence as well as the ability to attempt the assault course, a fifteen-mile route march, and a cross-country run were essential.

Twenty-five patients failed to attain this standard. Twenty cases were graded downward into a disability category allowing only moderate stress and strain and five cases into a disability category for base duties only. The main cause of failure (in seventeen cases) was persistent quadriceps wasting, which responded very slowly to intensive treatment. Osteo-arthritis and osteochondritis dissecans each accounted for three cases of regrading, and ligamentous laxity accounted for two cases. It is considered that even more strict selection of the cases for operation is necessary to reduce this figure.

Of the patients who returned to front-line duty, the majority were infantrymen or gunners; and it was possible, one and two years later, to follow fifty-four such cases still further. In six instances there had been recurrence of pain, swelling, and instability of the knee joint sufficiently severe to necessitate hospital treatment.

These symptoms were produced by such relatively minor traumata of a twisting nature as resulted from jumping into trenches, walking over rough ground, or playing football. The author was fortunate enough to see three of these patients, and to obtain reports on the remainder. Without exception, the disability was due to a weak quadriceps muscle and the symptoms abated promptly on treatment by physiotherapy.

These patients returned to duty and maintained their categories, but it would appear likely that in the course of time a certain number will have knee joints which are more susceptible to minor injuries; if this weakness cannot be overcome by further development of the quadriceps muscles or if the symptoms tend to recur frequently, regrading will be necessary, thus increasing still further the percentage of failures.

CONCLUSIONS

Meniscectomy is an operation of value in the soldier only in carefully selected cases of internal derangement of the knee joint. Under campaign conditions the operation is not justified in the presence of osteo-arthritis, osteochondritis, or weakness of ligaments or muscles.

Total meniscectomy is preferable in order to exclude multiple meniscus lesions, and does not appear to cause excessive operative trauma to the joint.

Preoperative and postoperative physiotherapy are of as great importance as operative technique.

The majority of patients can be expected to be fit for duty within two months after operation, but in actual practice, for troops in the forward area, three months' absence from the unit is to be expected.

NOTE: The author's thanks are due to Brigadier Harold Edward, Consulting Surgeon, and to Lieutenant Colonel A. J. Watson, R.A.M.C., Adviser in Orthopaedics, for their unfailing help and advice; and to the nursing and physiotherapy staffs of the British General Hospitals, where these cases were treated. The patients themselves responded loyally to follow-up requests, and Major C. D. Kelly, R.A.M.C., at a Convalescent Depot, very kindly supplied useful case details.

REFERENCES

CAVE, E. F.; ROWE, C. R.; AND YEE, L. B. K.: Selection of Cases for Arthrotomy of the Knee in an Overseas General Hospital. A Two-Year Follow-up Study. J. Bone and Joint Surg., **27**: 603–607, Oct. 1945.

DUTHIE, J. J. R., AND MACLEOD, J. G.: Rehabilitation after Meniscectomy. Experience at Army Convalescent Depot. Lancet, **1**: 197–199, 1943.

Meniscectomy in Soldiers. Review of Cases Discharged from an Army Convalescent Depot. Lancet, **1**: 182–183, 1944.

MACFARLANE, J. A., AND MACKENZIE, D. W.: Internal Derangement of Knee Joint. A Survey of 303 Cases Coming to Operation in General Hospitals of Canadian Army (Overseas). J. Canadian Med. Services, **1**: 41–48, Nov. 1943.

MACKENZIE, D. W., AND MACFARLANE, J. A.: Internal Derangements of the Knee Joint in the Canadian Army (Overseas). Canadian Med. Assn. J., **49**: 472–478, 1943.

EXPERIENCES WITH THE BRITTAIN ISCHIOFEMORAL ARTHRODESIS *

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For a number of years the writer has been dissatisfied with the rather high incidence of failure of osseous fusion following the use of the standard iliofemoral operations, especially in the tuberculous hip. Frequently, osseous fusion has not been accomplished, even after a second operation. Other surgeons have had similar experiences. In 1942, Badgley and Hammond published the end-result study of seventy-one cases in which fusion operations had been performed on tuberculous hips. They reported osseous ankylosis, requiring an average time of five years, in 52 per cent. An additional 22 per cent. of the patients had satisfactory results, but with fibrous ankylosis and variable symptoms. The failure of the iliofemoral operation has been due to the distraction effect of the adductor muscles on the superiorly and laterally placed graft; and, in some cases, to the presence of diseased bone in the superior portion of the acetabulum.

Brittain has pointed out that the mechanical strength of the ischiofemoral strut graft, placed inferior to the hip joint, is superior to that of the flying-buttress graft of the iliofemoral type. The former heals under a compression force, while the latter must heal under tension; the force in both instances is supplied by the adductor muscles of the hip and thigh.

Healing of tuberculous lesions of the hip has been reported by Kofmann and Tarlo, in 1935, and by Farkas, in 1939, as being hastened by subtrochanteric osteotomy. This operation allows the adductors—at least temporarily—to immobilize the hip joint without the sacrifice of a good functional position for fusion of the limb as a whole. Bosworth, in 1942, reported nine cases of tuberculous disease of the hip joint, treated by ischial transplantation of the proximal end of the distal femoral fragment after a subtrochanteric osteotomy. Of the nine patients, osseous ankylosis developed in five, two died, fusion failed in one, and one had been operated upon too recently for the end result to be known. Brittain has ingeniously combined the intertrochanteric osteotomy with the ischial transposition of the femur, reinforced and stabilized by a massive tibial graft to supply osteogenic substance. It is of interest that Brittain reported his first operation on February 20, 1936, and Bosworth his first—without the graft—in December 1936.

Brittain reported thirty-five cases of ischiofemoral arthrodesis,—nineteen in tuberculous disease of the hip. Of these, 80 per cent. healed by osseous fusion after the first operation, and an additional 8 per cent. healed by subsequent surgery. Knight and Bluhm have reported nine cases of Brittain ischiofemoral arthrodesis for tuberculous hips; twelve operations were performed, because three cases were bilateral. Two of these cases were too recent to permit end-result studies. Of the seven cases in which results after one to two years were available, ten operations were represented. In six, osseous ankylosis took place; two grafts fractured; one graft was absorbed distally; and one graft was involved by the infection, but was healing.

The author performed seven Brittain ischiofemoral arthrodeses in a period of seven months—from April to November 1944—and waited six months to determine the results in these cases, prior to continuing this operative procedure. Although numerous additional operations have now been done, end-result studies are reported only for the seven patients operated upon from thirteen to twenty months previously. Of these, six were patients with tuberculous hips, whose ages varied from seven to eighteen years; five had proved tubercu-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

FIG. 1-A

FIG. 1-B

H.D., male, aged twelve years. Patient had proved tuberculosis of left hip, with quiescent abscess.
Fig. 1-A: Preoperative roentgenogram.
Fig. 1-B: Roentgenogram sixteen days after operation.

FIG. 1-C

FIG. 1-D

Fig. 1-C: Roentgenogram, seven months after operation, shows fusion.
Fig. 1-D: Seventeen months after operation. Patient was walking without support at seven months.

lous lesions. One patient, a woman of fifty-three, had a painful, disabling, degenerative arthritis following an ancient traumatic luxation of the hip.

RESULTS

Of the six patients with tuberculous hips (Table I), the results after ischiofemoral arthrodesis were as follows: Two patients (H. D. and M. M.) showed osseous fusion, clinically and by roentgenogram (Fig. 1-C), in seven months; one (A. J.) showed osseous fusion in eight months (Fig. 3-A); and one (S. C.) in nine months. In other words, fusion occurred in two-thirds of the patients in nine months. In one patient (N. K.), an incorrigible seven-year-old girl who broke her spica one month after operation and four times subsequently in the first five-month period after operation, firm fibrous union developed. She was asymptomatic and ambulatory, without support, sixteen months after operation. Now, three months later, she is still doing well. It was thought that in this instance the osteotomy alone hastened healing of the disease. In the sixth patient (R. N.), a woman twenty-two years old with a quiescent pulmonary lesion, renal tuberculosis developed one

month after operation. The spica was removed to make retrograde pyelograms at the end of four months; and again, eight months later, when a nephrectomy was done. Now, one year after the Brittain ischiofemoral operation, the hip has minimum motion clinically, and roentgenograms indicate apparent healing.

The one non-tuberculous patient (Sister P.), a moderately obese woman of fifty-three who had painful, disabling, traumatic arthritis of the hip, showed clinical and roentgenographic fusion in four months (Fig. 6-B); she had been up on crutches two months after operation. This patient walks with an almost imperceptible limp, sits well, and can kneel and again assume the upright position without assistance or unusual effort. Her hip is fused in 40 degrees of flexion, 20 degrees of external rotation, and 5 degrees of abduction.

Data concerning five of these patients—and the patients themselves—were presented at the meeting of the Clinical Orthopaedic Society in Cincinnati, October 1945, and the author believes it was generally agreed that the ischiofemoral fusions produced function as good as, if not better than, the fusion obtained by the iliofemoral procedures.

FIG. 2-A

M.M., female, eighteen years of age. Roentgenogram shows tuberculosis of left hip of eleven years' duration; right hip was normal.

OPERATIVE TECHNIQUE

The operative technique carried out has, with minor variations, been that described by Brittain in his book. In tuberculous patients, surgery has not been performed in the presence of active abscesses; and, as in the past, surgery has been postponed until the patient has shown an ability to control the tuberculous disease by conservative therapy.

With the patient on a fracture table, both lower extremities are fixed, with the diseased member as

FIG. 2-B

FIG. 2-C

Fig. 2-B: Shows proved tuberculosis of right hip, with abscesses of three years' duration. Conservative therapy was employed.

Fig. 2-C: Shows fusion of right hip, fifteen months after operation; weight-bearing had been possible for four months. Note intra-articular healing.

TABLE I

END RESULTS, THIRTEEN TO TWENTY MONTHS AFTER OPERATION, IN SIX PATIENTS WITH TUBERCULOUS HIPS AND ONE WITH TRAUMATIC ARTHRITIS

Patient	Age and Sex	Diagnosis	Onset of Disease	Brittain Operation	Fusion	Complications	Comments
H.D.	12 M	Tuberculosis left hip with quiescent abscess. Guinea pig positive.	May 1940	Apr. 8, 1944 Left hip. Right tibial graft.	Clinically Apr. 29, 1944 By x-ray Nov. 15, 1944	None	Fused in 7 mo. At 10 mo. full weight-bearing allowed. Asymptomatic
M.M.	18 F	Tuberculosis left hip; extensive atrophy and shortening.	1932				
		Tuberculosis right hip; recently healed abscess. Bacilli on direct smear.	Apr. 1941	May 1, 1944 Right hip. Right tibial graft.	Clinically Sept. 15, 1944 By x-ray Dec. 4, 1944	None	Fused in 7 mo. Full weight-bearing, asymptomatic 11 mo. after operation.
S.C.	7 M	Tuberculous spondylitis, 3rd and 4th lumbar vertebrae.	June 4, 1941				Vertebrae fused spontaneously.
		Tuberculosis right hip.	Dec. 26, 1941	May 6, 1944 Right hip. Right tibial graft.	Clinically Feb. 21, 1945 By x-ray Feb. 21, 1945	Graft high, into diseased area; partial absorption.	Fused in 9 mo. Patient still recumbent.
		Tuberculosis left hip.	Apr. 4, 1942				
N.K.	7 F	Tuberculosis right hip with sinus. Tubercle bacilli on direct smear.	Oct. 24, 1941	May 8, 1944 Right hip. Right tibial graft.	No osseous fusion.	Five broken spicas during first 5 mo. after operation.	Fibrous healing 16 mo. Jog of motion Sept. 10, 1945; no fixation since. Asymptomatic Dec. 10, 1945.
A.J.	17 M	Tuberculosis left hip.	Mar. 1943	Aug. 19, 1944 Left hip. Left tibial graft.	Clinically Apr. 25, 1945 By x-ray Apr. 25, 1945	Nov. 10, 1944 Some bone absorption, ischial portion graft; later recalcified.	Fused in 8 mo. weight-bearing begun. One year after operation, walking without support; asymptomatic
R.N.	22 F	Tuberculosis right hip. Pulmonary tuberculosis, quiescent.	1941	Nov. 11, 1944 Right hip. Left tibial graft.	No osseous fusion.	Right renal tuberculosis Dec. 1944. Right nephrectomy July 31, 1945. Cast removed for pyelograms 4 mo. after fusion.	One year after fusion, hip fusing in spite of nephrectomy, etc. Still in spica.
Sister P.	53 F	Traumatic arthritis right hip; old luxation. Disabling pain.	1921	Sept. 21, 1944 Right hip. Right tibial graft.	Clinically Dec. 14, 1944 By x-ray Feb. 21, 1945	Obesity	Fused in 5 mo. Weight-bearing in short spica 4 mo.; without spica, 5 mo. Asymptomatic Excellent function: kneels, etc.

FIG. 3-A

FIG. 3-B

A.J., male, seventeen years of age, had tuberculosis of left hip.

Fig. 3-A: Roentgenogram taken after seventeen months of conservative therapy.

Fig. 3-B: Shows left hip, eleven months after operation; fusion had been demonstrated, clinically and by roentgenogram, for three months. Patient was bearing weight.

FIG. 4-A

FIG. 4-B

S.C., male, seven years of age.

Fig. 4-A: Shows tuberculous spondylitis of third and fourth lumbar vertebrae; tuberculosis of right hip of three years' duration; and tuberculosis of left hip of two years' duration.

Fig. 4-B: Shows right hip, immediately after operation. Graft was too high and too long.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Three months after operation; graft being absorbed proximally.

Fig. 4-D: Fifteen months after operation; ischiofemoral fusion and intra-articular fusion have occurred.

nearly as possible in the ideal position for ankylosis. Two skin clips are applied,—on over Poupart's ligament at the junction of the middle and proximal thirds, and a secon *anteriorly*, just below the inferior border of the greater trochanter. While a film on a por able machine is being taken and developed, a full-thickness tibial graft from the same leg removed with a bone saw; the entire flat surface and the medial and anterolateral surface of the tibia are included, as is done by Brittain. The length of the graft varies with th size of the patient, and may be from three to five inches. The tibial wound is closed; th periosteum may be approximated easily because of the size of the graft removed. Throug a lateral incision, beginning at the middle of the greater trochanter and carried distall about three inches, the periosteum of the femur is split longitudinally, retractors are in serted, and the lesser trochanter is identified blindly with a narrow blunt dissector. Wit the skin clips and roentgenogram as guides (Fig. 7-A), a three-sixteenth-inch drill is in serted about an inch below the greater trochanter and directed, proximal to the lesse trochanter, in a plane planned to meet the base of the ischium, the pubis, or healthy sul acetabular bone; this plane depend upon the degree of bone destructio the angle of the proposed fusion, an variation in the specific osseous ana omy. Another roentgenogram i made. A cleanly cut intertrochanteri osteotom yis now done; one of tw identical osteotomes is used, wit graduated quarter-inch scales marke on the narrow edge of the one an one-eighth inch blades. The osteo tome is pushed gently but firmly medially in the *coronal plane* unti bony contact is made, and is driven a short distance farther. Usually this is a distance of from one to one and one-half inches from the media border of the femur. A third roent genogram is now made. If the pos tion of the osteotome is correct (an

FIG. 5-A

N.K., female, seven years of age. Roentgenogram shows proved tuberculosis of right hip, with healed sinus.

FIG. 5-B

FIG. 5-C

Fig. 5-B: Shows right hip, soon after operation; graft was rather high, with too little displacement of femur.

Fig. 5-C: Thirteen months after operation *fibrous healing* had occurred, without symptoms. Cast had been broken five times in first five months after operation.

usually is), with moderate traction on the limb, the second osteotome is placed on top of the first and, with the scale of the first osteotome as a guide, is driven into the ischial bone for a distance of from one-half to one and one-half inches, depending upon the size of the patient. The second osteotome is withdrawn and the tibial graft, with its medullary surface down and its proximal end beveled, is inserted along the surface of the first osteotome. After the graft touches the pelvic bone, it is driven in solidly. The first osteotome is now withdrawn. While some traction is maintained on the leg, *without increasing the abduction*, the proximal end of the distal fragment is displaced medially until contact with the bone is felt; a wide bone impacter is used. Following this simple procedure, the author has experienced no difficulty in displacing and maintaining the distal fragment medially transposed. The medial cut in the femoral periosteum produced by the osteotome has sufficed in more than a dozen operations, and there has been no indication that the periosteum also needs to be severed by a scalpel, as suggested by Knight and Bluhm. While the wound is being closed in a routine manner, a final roentgenogram is made. A long single spica or a double hip spica is applied, which includes the foot and extends to the mid-thoracic level. The tibial graft is removed from the same limb upon which arthrodesis is

FIG. 6-A

Sister P., female, fifty-three years of age. Patient had painful traumatic arthritis of right hip, of twenty-three years' duration.

FIG. 6-B

FIG. 6-C

Fig. 6-B: Four months after operation there was clinical and roentgenographic fusion of right hip, with full weight-bearing.

Fig. 6-C: Note massive fusion of right hip, one year after operation. Functional result was excellent.

being performed; no protection of the other limb is necessary. The fused hip is sur prisingly stable at the completion of the operation. The lessened discomfort occasione by a single spica, especially in an adult, and the stability of the hip have warranted its us in several instances.

The relative positions of the intertrochanteric area of the femur and the ischium ar

FIG. 7-A

FIG. 7-B

L.G., female, twenty-two years of age.

Fig. 7-A: Patient had painful posttraumatic aseptic necrosis of right hip. Shows guide drill and skin clips used during surgery.

Fig. 7-B: During operation, osteotome has replaced guide drill.

FIG. 7-C

One and one-half months after operation, graft and femoral apposition are ideal. Callus is forming along graft.

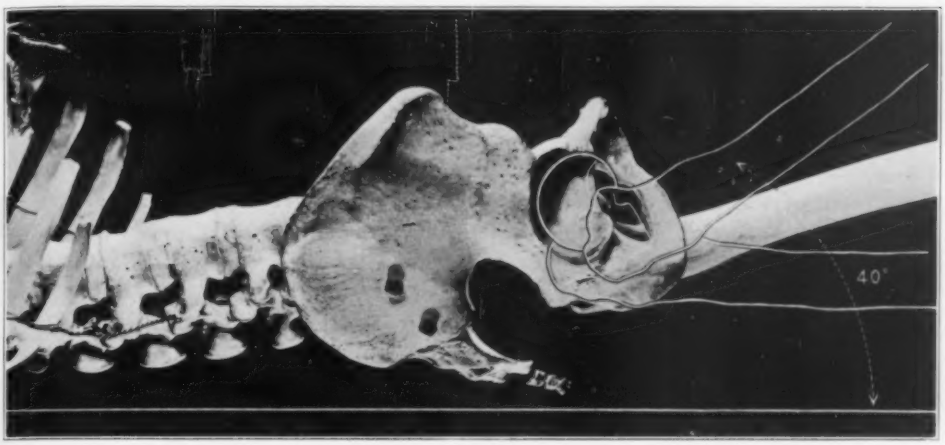

FIG. 8

Photograph of skeleton, with left femur moderately flexed. Tracing of right femur in approximately 15 degrees of external rotation. For children, with hip in extension, intertrochanteric area in coronal plane overlies ischium. For adults, with hip flexed 40 degrees, intertrochanteric area partially overlies ischium. Note obliquity of obturator foramen. A graft, the full width of the tibia, would strike the ischium or pubis, but could not enter the obturator foramen without coming into contact with bone, if introduced in the coronal plane.

FIG. 9-A

FIG. 9-B

R.T., male, forty-five years of age.

Fig. 9-A: Shows Charcot hip, before operation.

Fig. 9-B: Two months after operation. Patient had postoperative bilateral oedema of lower extremities and pelvis; cast was radically split; and graft and femur shifted spontaneously. Nevertheless, osteotomy is healing, and graft is viable. If fusion fails, hip should be stable.

shown in Figure 8. With the lower extremity rotated externally 20 degrees for ideal function, the trochanter lies posterior to the plane of the femoral head and to the acetabulum. In children the hip is fused in extension, with allowance for some flexion to develop during subsequent growth. In adults, with the femur flexed about 40 degrees, the intertrochanteric area—or site of osteotomy—in the coronal plane overlies approximately the anterior third of the ischium. In the coronal plane, the full-width tibial graft is wider than the obliquely situated foramen. Therefore, if the osteotome and graft should fail to come into contact with the ischium, they must meet either the subacetabular bone or the base of the pubis. Free, non-osseous entrance into the obturator foramen has not occurred.

DISCUSSION

The basic principles of the Brittain ischiofemoral operation are simple. An adequate, rigid tibial graft must be firmly implanted in healthy pelvic bone. The proximal end of the distal femoral segment must be displaced medially to the ischium, so that new bone need not develop across a dead space bridged only by the graft. Uniform contact between the cut surfaces of the femur and the graft ensures moderate immediate fixation, early healing, and maintenance of the original operative position. If the hip joint has limited mobility at the time of operation, satisfactory apposition of the femoral surfaces and the graft should not be sacrificed in an attempt to perfect the angle of the fusing hip. This is the principle followed in the treatment of any fracture,—traumatic or surgical. Early release of the external fixation, whether accidental or intentional, may jeopardize the end result. The only instance in the author's experience where the graft became displaced was after a drastic splitting of the spica, two weeks after operation; it was indicated by extensive oedema of both lower extremities, extending up to the waist. This was in the patient with a Charcot hip (R. T.). Following the disappearance of the oedema, a new spica was applied. Although the graft became somewhat displaced, two months after operation fusion appeared to be developing (Fig. 9-B).

In patients with tuberculous lesions, the osteotomy should obviously be done at a level and at an angle which will allow the graft to be imbedded in bone not involved in the infectious process. In one patient (S. C.), partial absorption of the graft (Fig. 4-C) followed apparent extension of the disease from the acetabulum into the graft. In this instance, however, the end result was a satisfactory osseous fusion.

There is no need for a great degree of obliquity of the osteotomy; rather, a firm apposition of the femoral fragments with the graft and satisfactory imbedding of the graft should be sought. Depending upon the specific relations of the damaged hip joint, the angle of osteotomy should vary from the transverse plane to an angle of 45 degrees.

Although end results are reported on only seven cases, the high percentage of osseous fusion obtained, the relative simplicity of the operative procedure, and the absence of shock have convinced the writer that this Brittain method of performing hip-fusion operations should be given an extensive trial by orthopaedic surgeons. The indications for Brittain ischiofemoral arthrodesis are multiple; one of these is in Charcot's hips, which were previously amenable to arthrodesing operations only in the earliest phases of the disease. The contra-indications for this operation occur in those few instances where diseased bone cannot be "short-circuited" by the osteotomy and graft. One such tuberculous hip has been encountered during the past year, with a large calcifying abscess situated between the intertrochanteric area of the femur and the ischium.

CONCLUSIONS

Of six patients with tuberculous hip joints upon whom the Brittain ischiofemoral arthrodesis was performed, osseous fusion developed in four within from seven to nine months. In one case, with postoperative extraneous complications, fusion is apparently taking place after one year. In one adult, a painful, disabling traumatic arthritis of the hip was healed by osseous fusion in four months. Additional patients * upon whom this operation has been performed are showing every evidence of a similar high percentage of osseous fusion.

The Brittain ischiofemoral arthrodesis ideally combines an intertrochanteric osteotomy, which allows temporary joint rest, and an inferiorly placed strut graft; healing occurs under compression stresses, rather than tension stresses, as in the iliofemoral operations.

* Since this paper was prepared six additional Brittain fusions have been done, with results as satisfactory as those reported.

REFERENCES

Badgley, C. E., and Hammond, G.: Tuberculosis of the Hip. A Review of Seventy-Six Patients with Proved Tuberculous Arthritis of Seventy-Seven Hips Treated by Arthrodesis. J. Bone and Joint Surg., **24**: 135–147, Jan. 1942.

Bosworth, D. M.: Femoro-Ischial Transplantation. J. Bone and Joint Surg., **24**: 38–46, Jan. 1942.

Brittain, H. A.: Ischiofemoral Arthrodesis. British J. Surg., **29**: 93–104, 1941–42.

Brittain, H. A.: Architectural Principles in Arthrodesis. Baltimore, The Williams and Wilkins Co., 1942.

Farkas, A.: A New Operative Treatment of Tuberculous Coxitis in Children. J. Bone and Joint Surg., **21**: 323–333, Apr. 1939.

Knight, R. A., and Bluhm, M. M.: Brittain Ischiofemoral Arthrodesis. J. Bone and Joint Surg., **27**: 578–586, Oct. 1945.

Kofmann, S., und Tarlo, R.: Über die aktive Richtung in der Therapie der Knockentuberkulose. Ztschr. f. orthop. Chir., **62**: 415–426, 1935.

DISCUSSION

Dr. Carl C. Chatterton, St. Paul, Minnesota: I am sure we have enjoyed this excellent paper of Dr. Freiberg's, describing a good arthrodesis, extra-articular, of the hip joint; and it is my belief that, in the future, a greater number of extra-articular fusions of the hip joint will be of this type.

At the Gillette State Hospital, a Minnesota institution for crippled children, from July 1, 1924, to December 10, 1945, forty-six arthrodeses of the hip have been done. We find in this number that four were the Albee type, three were the Brittain type, one the Henderson type, nine the Hibbs type, and twenty-nine the Wilson type of fusion. Of these forty-six fusions, seven were refusions.

There was one case in which a fibrous fusion of the hip was progressing satisfactorily; therefore, there were really thirty-nine cases taken care of, with seven refusions and one hip which was still not stable.

At this Institution the time spent in the Hospital is not especially considered. All of the patients remained until their hips were in satisfactory condition; and the interesting thing to me was the deformity which took place, in spite of bony arthrodesis. We find in going over the cases that there were ten which required osteotomy for correction of deformity,—that is, of flexion and adduction. No patients have died as a direct result of the operation, but three have died since the date of operation.

In all of these cases except two, the arthrodeses were done because of a tuberculous condition.

I do believe that the point which Dr. Freiberg makes in his paper—namely, that the adductor muscles help stabilize the graft—is a very important consideration; practically all of the cases taken care of at Gillette Hospital which required operation for deformity were for deformity of flexion and adduction, especially adduction. There are several patients walking around with their hips flexed as much as 45 degrees, upon whom operation has not been done. Therefore, I can only recommend the Brittain operation after our experience with three patients whose hips have remained in excellent position.

Upon further reviewing the cases, we find that we had incomplete fusions after five Wilson operations and two Albee operations. The Hibbs operation in nine cases resulted in fusion in every instance. One of the Brittain operations did not produce solid fusion, but I felt that the time period had been too short for us to be absolutely sure that union was not going to take place. The record also shows that the greater number of Wilson operations were done on children under ten, while the Hibbs and Albee operations were done on older children. Of course, the Brittain operation can be done at any time, practically regardless of age.

I do believe at this time that the Brittain operation is the best extra-articular fusion for securing an ankylosis in tuberculous disease of the hip joint.

Dr. Robert A. Knight, Memphis, Tennessee: Dr. Freiberg has brought to our attention a valuable method for inducing arthrodesis of the hip joint. Its advantages are many and its disadvantages and complications are relatively few.

Some of the complications in connection with this procedure have occurred in regard to the following points:

1. *Improper Selection of Cases*: The chief contra-indication in this respect has been the occasional case in which there is downward extension of the tuberculous process into the ischium. Also, one case of tuberculosis of the hip joint with an associated tuberculosis of the trochanteric bursa was not considered satisfactory.

2. *Improper Insertion of the Graft into the Ischium*: In one instance, the tuberculous disease involved the graft as a result of insertion of the graft into the diseased portion of the ischium. A sinus

formed, and secondary infection followed. Fortunately, involucrum formation eventually proved adequate to give a solid ischiofemoral arthrodesis, despite sequestration of a portion of the graft.

3. *Incomplete Medial Displacement of the Shaft of the Femur Against the Ischium*: Complete medial shifting of the shaft hastens consolidation of the fusion mass, which consists of the ischium, graft, and proximal end of the femur, and reduces the strain upon the graft. The strain from incomplete medial displacement has been responsible for fracture of the graft and for absorption about the outer end of the graft, which took place in our early cases, where displacement was incomplete. These complications greatly prolonged the period of necessary immobilization after operation.

My experience with this method has been almost entirely confined to cases of tuberculous disease of the hip joint, but its use in other types of disease of the hip joint requiring arthrodesis is apparent. It is probably the most rational and practicable method of obtaining arthrodesis in Charcot's disease of the hip joint, and I am most impressed with Dr. Freiberg's use of it in his case of Charcot's disease.

Dr. David M. Bosworth, New York, N. Y.: When similar operations—such as the femoro-ischial transplant or the Brittain operation—are first introduced, it would seem that one or the other would supplant its alternate in usefulness. As time goes on, however, one may find different indications of usefulness for each procedure. Neither of them supplants routine hip fusion, where the bony parts of a hip joint remain relatively intact and in position and where mixed infections are not present. The percentage of absolute ankyloses reported by each procedure to date is about equal. For a femoro-ischial transplant to work well, considerable shortening and displacement upward of the trochanteric portion of the shaft must have occurred. Under such circumstances, gain in length can be secured by transplantation to the ischium under tension, by using a grooved pry. In such situations the Brittain operation not only fails to gain length, but actually allows for shortening. The upper end of the femur slides inward and upward under the oblique lower margin of the tibial graft, which has been inserted, through the osteotomy site, into the pelvis. In cases where only moderate crumbling of the head of the femur and slight upward displacement are present, there is so much relaxation after a femoro-ischial transplant that instability results. In such cases the Brittain operation is excellent. Even here, however, it is excellent only if so much disorganization has occurred that routine hip fusion cannot be done.

Where a mixed infection is present in the hip joint, one should not expect that surgical exposure by either the Brittain operation or the femoro-ischial transplant will remain outside the infected area. We have shown that, normally, extension of the synovial membrane of the hip joint downward to the level of the lesser tuberosity of the femur occurs. The placing of a graft or the cutting off of the femoral shaft at this level, therefore, may traverse infected tissue. I believe that this accounts for the disorganization of some of the Brittain grafts, and for the occasional flare-up of infectious lesions by femoro-ischial transplants. There is always the great advantage in a femoro-ischial transplant that additional separate dead bone fragments need not be implanted, and that a second ostectomy site need not be created. As regards this latter, our records have led us to expect, in approximately 10 per cent. of the cases, pathological fracture of the tibia following ostectomy in securing grafts.

To crystallize our feeling, therefore, we would judge that hip fusion should be done whenever possible; that the Brittain operation might prove preferable where only moderate disorganization of the femoral head and neck were present and but little upward displacement of the trochanteric area existed; and that the femoro-ischial transplant would be the method of choice where massive destruction of the head and neck of the femur had occurred and marked upward displacement of the trochanteric portion beyond the acetabulum was present.

SYMPATHETIC BLOCK OF THE STELLATE GANGLION

Its Application in Orthopaedic Conditions *

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Sympathetic block, a development of the observation that areas made anaesthetic through local injection show increased surface temperature, has become a most important branch of regional anaesthesia. A plausible explanation for this effect has been suggested by Ochsner and DeBakey: "As a result of vasospasm there occurs increased filtration pressure, anoxia of the capillary endothelium, and diminution in the flow of lymph, setting up a vicious circle. Interruption of the vasoconstrictor impulses by procaine hydrochloride block of the regional sympathetics breaks this vicious circle by increasing pulsations, improving circulation and tissue oxygenation, and increasing lymph flow." The diagnostic, prognostic, and therapeutic applications of sympathetic block to the lower extremity are well known and have been employed frequently. In contrast, regional block of the sympathetic nerves supplying the upper extremity has been neglected. Stellate block is not only equally applicable to similar conditions of the upper extremity, but to many other painful conditions as well.

The authors have employed infiltration of the stellate ganglion with procaine hydrochloride in approximately 400 cases of painful orthopaedic lesions in the upper extremities, from which they have selected for presentation eighteen cases of acute subdeltoid bursitis; twelve cases of periarthritis; five cases of myositis and fibrositis; eight cases of hypertrophic arthritis; five cases of the infectious arthritides; twenty-five cases of pain and swelling following trauma (fractures, dislocations, and contusions); and five cases of causalgia following trauma (Table I). In each category, only those cases have been chosen which have been followed carefully.

1. *Acute Subdeltoid Bursitis*

Acute subdeltoid bursitis is characterized by pain, swelling, heat, redness, and tenderness, localized over the bursa; and by limitation of shoulder motion because of pain. Eighteen patients with this condition were treated by stellate block. The patients ranged in age from nineteen to seventy-eight years; the average age was 42.6 years. Five of the patients were women. The average duration of symptoms was 5.8 days. Most of the patients had been treated previously by the application of heat, massage, or immobilization, or by a combination of two or more of these measures; only four patients had had no previous treatment. Immediate relief was classified as excellent in 83.3 per cent. and as good in 16.7 per cent. of the cases. Fifty per cent. of the patients obtained considerable relief from pain after one block; the remainder required additional blocks at intervals of from one to seven days; but in all the pain was relieved subsequently. Striking improvement in motion in the joint was noted in all cases, and this usually developed within a few minutes after a successful block.

2. *Periarthritis*

This condition is a sequel of acute bursitis, in which adhesions form in and about the bursa and involve the periarticular structures. Motion is limited, because of the pain and adhesions. Although symptoms are usually of longer duration, they are not so severe as in

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 21, 1946.

TABLE I

PAINFUL ORTHOPAEDIC LESIONS IN SEVENTY-EIGHT PATIENTS TREATED BY STELLATE BLOCK

Diagnosis	Number of Cases	Average Age (*Years*)	Average Number of Blocks	Results						
				Immediate			Remote			Not Followed
				Good (*Per cent.*)	Fair (*Per cent.*)	Poor (*Per cent.*)	Good (*Per cent.*)	Fair (*Per cent.*)	Poor (*Per cent.*)	
Acute subdeltoid bursitis	18	42.6	1.8	100			77.7	16.6		5.5
Periarthritis	12	56.7	2	100			50.0	41.7	8.3	
Myositis and fibrositis	5			100			80.0	20.0		
Hypertrophic arthritis	8			100				50.0	37.5	12.5
Infectious arthritides	5			80	20		40.0		60.0	
Posttraumatic pain and swelling	25		1.7	100						
Posttraumatic causalgia	5			80		20				

the group with acute inflammation. After subsidence of the pain, these patients were treated routinely by the application of heat, light massage, and relaxed circumduction. In this series of twelve cases of periarthritis, the ages ranged from thirty-six years to seventy-nine years, with an average age of 56.7 years. Symptoms lasted an average of 32.6 days. Half of the patients in this group were women. The average number of blocks required for relief was two, at intervals of from one to seven days. The end results in this group were not so striking as those in the patients with acute subdeltoid bursitis, but this was to be expected in view of the structural changes which occur in such cases. However, pain was relieved sufficiently to make possible a much more active range for the institution of physical therapy.

3. *Myositis and Fibrositis*

These conditions are characterized by diffuse involvement of a group of muscles; the involvement may be acute or chronic. The patient often gives a history of previous muscle strain or of unusual exposure. The condition is analogous to the more widely known lumbar myofascitis.

Since there were only five cases in this group, statistical analysis is not possible. It was noted, however, that eventual relief was secured over a longer period of time; this observation tends to minimize the role played by the blocks. The relief obtained was probably due to anaesthetization of the communicating branches to the fifth and sixth cervical nerves from the middle cervical ganglion.

4. *Hypertrophic Arthritis*

This is a painful inflammation of the elbow, shoulder, or hand, following formation of new bone at the articular margins and degeneration of the articular cartilage. It is usually seen in middle-aged persons who also show involvement of other joints. The ages in this group ranged from forty-three years to seventy-nine years. Six of the eight patients were women. The duration of symptoms varied from three weeks to two years. Most of the patients had previously been treated with salicylates and the application of heat. More

than one block was required in all but one case. Relief from pain was transitory, and this was apparently due to the irreversible tissue changes which had already occurred.

5. *Infectious Arthritides,—Specific and Non-Specific, Acute and Chronic*

Five men, ranging in age from seventeen to forty-nine years, with infectious arthritis of from five weeks' to three years' duration, had between one and three blocks at intervals of from one to seven days. Only temporary relief from pain was obtained. Repeated blocks, by making the condition more tolerable, might also make it more amenable to specific treatment.

6. *Pain and Swelling Following Trauma (Fractures and Dislocations)*

Seventeen patients with pain and swelling following fractures or dislocations were included in this group. Stellate block was done after reduction of the fractures and dislocations; the relief of pain and diminution in swelling were so pronounced in the majority of cases that the authors now use this procedure almost routinely for patients complaining of pain and "tight casts". In this group, the ages varied from fifteen to seventy-four years. Seven of the seventeen patients were men. The series included cases of anterior dislocation of the shoulder, fracture of the spine of the scapula, fracture of the surgical neck, fractures of the upper and middle thirds of the humerus, Colles's fracture, fractures of the fingers, and supracondylar fractures of the humerus. The number of blocks averaged 1.94, at intervals of from one to seven days. The immediate result was excellent, and in many cases it was possible to avoid cutting casts which formerly would have required splitting.

7. *Pain and Swelling Following Trauma (Contusions)*

In this group of eight cases of pain and swelling following contusions, relief of pain was almost immediate,—presumably because of the relief of vasospasm secondary to the direct trauma. The ages ranged from twelve to fifty-two years, with an average of 32.5 years. Two of the eight patients were men. When these patients were seen after an interval of one week, their pain had uniformly subsided; this may have been due to the natural resolution of the process, but apparently the blocks also hastened it.

Mahorner used sympathetic blocks in a number of conditions for residual posttraumatic pains and for causalgia, and commented upon the remarkable relief from pain in at least 75 per cent. of the cases. In many of these cases pain was "the only residual which would interfere with an otherwise satisfactory or perfect result".

8. *Posttraumatic Causalgia and "Phantom" Pain After Amputation*

In these five cases there was definite injury to the nerves. All but one of the patients were men; their ages ranged from twenty-six to fifty-four years. The cases included traumatic amputation of two fingers, dislocation of the left shoulder and paralysis of the deltoid muscle, traumatic amputation of the right hand, compound shotgun fracture of the right elbow, and compound fracture of the left elbow.

Again it was found that blocks, as a rule, gave excellent relief from pain and diminution of swelling. One patient in this group suffered from intolerable causalgia after a crushing injury to his hand. Complete and immediate, but transient, relief followed blocking; and this was carried out twice a week for six months (a total of fifty blocks) before the patient decided to have a ganglionectomy. We have not had the opportunity to try blocks for "phantom" pain following amputation of the upper extremity, but the procedure proved of definite value in two cases of mid-thigh amputation. Leriche and Fontaine relieved neuralgia of the amputation stump by this method. Livingston reported ten cases of amputation of the upper extremity with classical "phantom" pain. All of these patients had one or more injections of procaine hydrochloride near the thoracic sympathetic ganglia of the affected side. "In 8 of the cases the patient felt immediate relief from pain, together with an extraordinary sequence of subjective and objective changes."

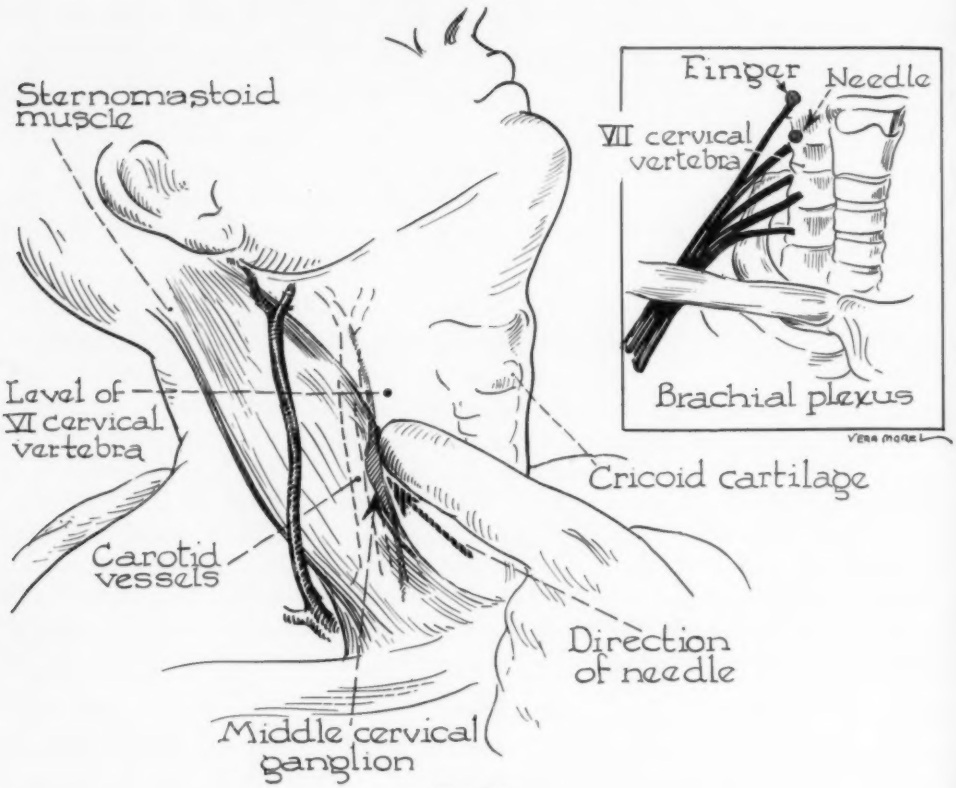

FIG. 1-A

In Technique I, the patient is supine, with the head rotated to the opposite side to make the sternocleidomastoideus stand out. The sixth cervical vertebra is located in relation to the seventh cervical spinal process posteriorly, and to the cricoid cartilage anteriorly. The finger, inserted toward the sixth cervical transverse process, displaces sternocleidomastoideus and carotid-sheath structures laterally, and trachea medially. The finger is pushed in until it touches the sixth cervical transverse process or the region of origin of the scalenus anterior, and is held there. The needle is inserted directly below and parallel to the finger, until it touches or approximates the transverse process.

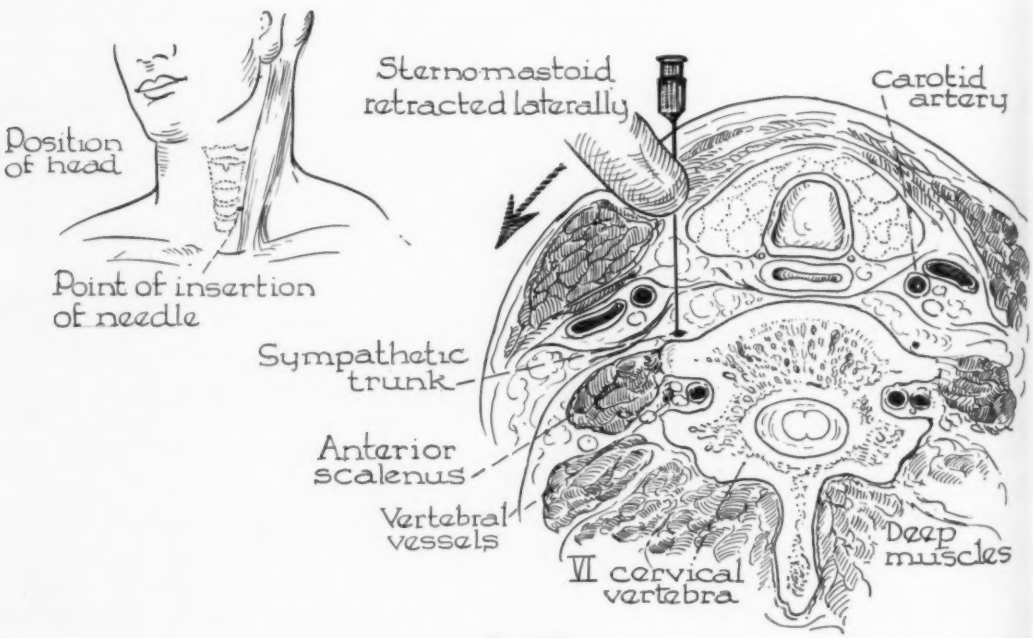

FIG. 1-B

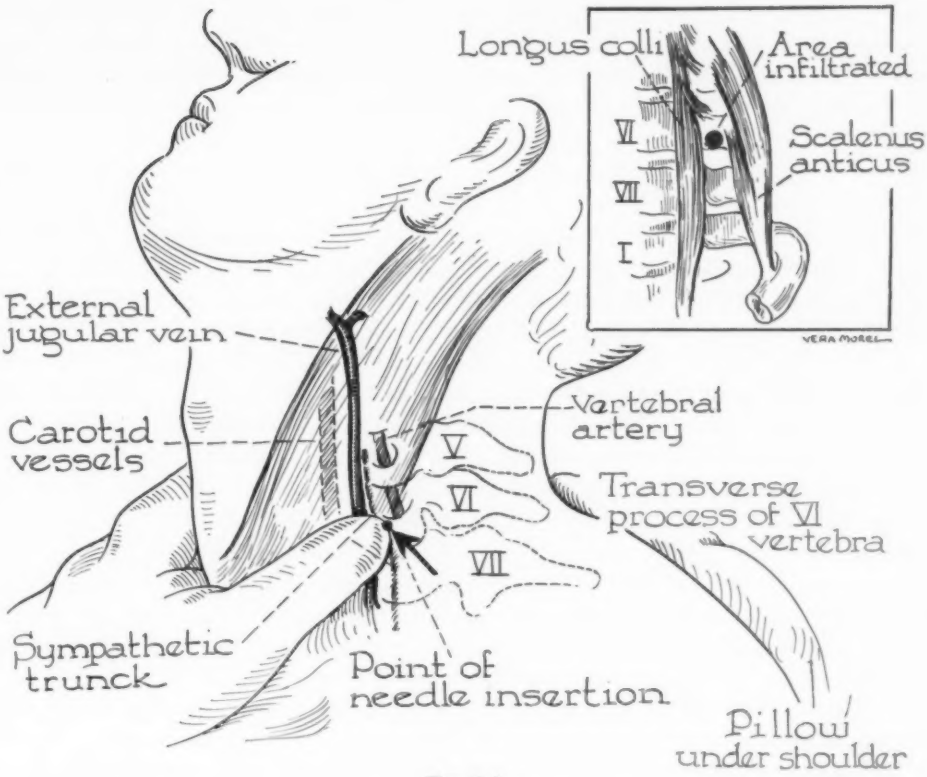

FIG. 2-A

In Technique II, the patient is supine. The head is turned up and away from the side to be blocked, in order to make the sternocleidomastoideus stand out. The sixth cervical transverse process is located as before (See Figs. 1-A and 1-B). The sternocleidomastoideus and external jugular vein are displaced anteriorly and the needle is inserted at right angles to tip of thumb, which is held on posterior margin of sternocleidomastoideus, anterior to the sixth cervical transverse process.

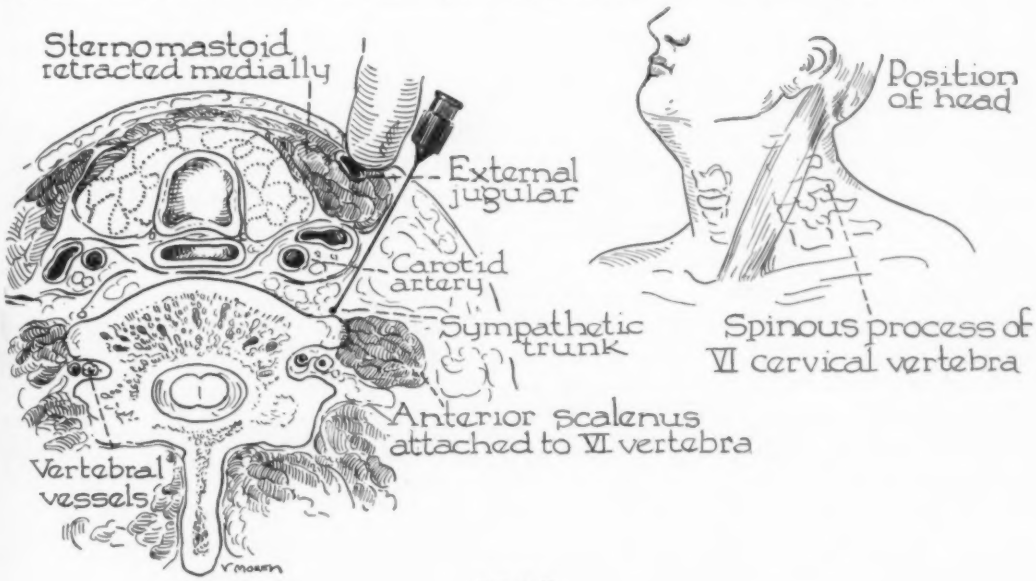

FIG. 2-B

DISCUSSION

The results obtained from stellate block in these cases indicate that the procedure is of definite therapeutic value in certain orthopaedic conditions. The infrequency of its use

can be attributed to lack of a routinely successful approach; fear of vascular, neural, or pulmonary complications; and uncertainty as to its indications. As in other surgical procedures, careful study of the anatomy and landmarks involved, an understanding of the technique, and an awareness of possible complications will greatly reduce the risk.

PROCEDURE

The authors have tried all the approaches that they could find described in the literature and have obtained the most consistently satisfactory results from modifications of the descending-infiltration technique of de Sousa Pereira. In an excellent paper, he describes the well-known anatomical features; and also points out the importance of the aponeurosis at the base of the neck, which acts as a pathway of diffusion for the anaesthetic solution from the level of the transverse process of the sixth cervical vertebra to the middle cervical and stellate ganglia. By utilizing this pathway, one can obtain consistently good blocks with needles of Wassermann or hypodermic length, instead of the usual and more lethal spinal-length needle. These "short-needle" techniques have enabled the authors to do stellate blocks with greater safety, ease, and speed than is possible with any of the other methods.

Technique I (Figs. 1-A and 1-B): The patient is given one of the shorter-acting barbiturates thirty minutes prior to infiltration. With the patient supine and the head flexed slightly on a pillow and rotated away from the site of injection, the manipulating finger is placed approximately one and one-half inches above the sternoclavicular junction. Pressure is exerted toward the transverse process of the sixth cervical vertebra, which is easily located in relation to the prominent seventh cervical spinous process and to the cricoid cartilage, anteriorly. Forcible displacement of the sternocleidomastoideus and carotid-sheath structures laterally, and of the trachea and oesophagus medially, is produced. With further inward pressure, the medial border of the scalenus anterior muscle can be felt. The finger tip is held at this point, in relative contact with the transverse process of the sixth cervical vertebra, which is palpable in some cases. After a skin wheal has been raised, a 22-gauge or 24-gauge needle, one and one-half to two inches long, is inserted below and parallel to the palpating finger, until its point either touches or approximates the lower border of the transverse process. The syringe is then removed from the needle, and the fluid in the hub is watched while the patient inspires deeply. If the needle is within the pleural space, fluid will be sucked in. Fluid will well out if the subarachnoid space has been tapped. The syringe is reinserted and, if no blood is obtained on aspiration, one cubic centimeter of 2 per cent. procaine hydrochloride is injected slowly. If no untoward reaction occurs, an additional four cubic centimeters is injected after aspiration; the needle is removed; and the patient is helped to a sitting position. If a good block has been obtained, conjunctival injection appears almost immediately and precedes the miosis, ptosis, exophthalmos, and anhidrosis typical of Horner's syndrome. If vasomotor block and pain block of the upper extremity do not appear within fifteen or twenty minutes, even though Horner's syndrome has developed, it is probable that diffusion of the anaesthetic has been insufficient for complete block of the stellate ganglion. De Sousa Pereira advises that, when this occurs, reinfiltration be performed inferiorly, toward the base of the seventh cervical transverse process.

Technique II (Figs. 2-A and 2-B): Another approach, which is employed by Patzer, is easier to perform, particularly in thin persons. With the patient supine, the transverse process of the sixth cervical vertebra is palpated posterior to the external jugular vein and behind the posterior border of the sternocleidomastoideus. The palpating finger then displaces the sternocleidomastoideus and the carotid sheath medially; and infiltration is effected, as before, anterior to the transverse process of the sixth cervical vertebra and medial to the border of the scalenus anterior.

COMPLICATIONS OF STELLATE BLOCK

Several possible complications may follow stellate block of the sympathetic ganglia of the upper extremities.

Psychic reactions are manifested by mild, transient signs of syncope, palpitation, perspiration, weakness, and excitement; they can be controlled by assurance and sedation.

Procaine reaction—fortunately, a rare occurrence—is evidenced by excitement, palpitation, and dyspnoea, followed by convulsions and respiratory failure, and terminating possibly in death. Such a serious development can usually be prevented by close observation after the initial small injection. If this reaction occurs, the patient should be given barbiturates intravenously, and oxygen should be administered. A prophylactic skin test is advisable as a routine procedure.

Pneumothorax occurred in one case after a block by the "long-needle" technique. Dyspnoea and thoracic pain were slight, and subsided completely after twenty-four hours of treatment by bed rest and the administration of nasal oxygen.

Hematomata following perforation of an artery or vein occurred in six cases, but were of no consequence, except that they precluded the injection of procaine.

Subarachnoid injection is a fatal complication, but one which is absolutely avoidable.

Recurrent laryngeal paralysis and *phrenic block* are manifested by transient hoarseness, aphonia, and unilateral paralysis of the diaphragm. The symptoms recede spontaneously. Obviously, bilateral block of the stellate ganglion should never be contemplated.

CONCLUSIONS

In cases of recent acute lesions of the upper extremity, stellate block affords relief from pain which is almost universally gratifying. These patients submit to, or even seek out, consecutive blocks. That the pain is probably vasospastic in origin is suggested by the fact that complete relief follows one or more blocks at frequent intervals. Clinical substantiation is evidenced by the results obtained in acute inflammatory and posttraumatic conditions, in which the major etiological factor is known to be circulatory impairment.

In chronic cases, in which the lesions have been present until such anatomical changes as adhesions, erosion of cartilage, or aberrant calcification supervened, it is obvious that only transitory relief from pain can be obtained. Adjunctive physical therapy should be employed in such cases. The range of physical therapy tolerated is in direct proportion to the relief of pain afforded by stellate block; and, in cases showing definite but transient improvement, it may be well to consider blocking with more noxious chemicals, such as alcohol derivatives; or even employing sympathectomy.

REFERENCES

Leriche, R., et Fontaine, R.: L'anesthésie isolée du ganglion étoilé: Sa technique, ses indications, ses résultats. Presse Méd., **42**: 849–850, 1934.

Livingston, W. K.: Fantom Limb Pain. A Report of Ten Cases in Which It Was Treated by Injections of Procaine Hydrochloride Near the Thoracic Sympathetic Ganglions. Arch. Surg., **37**: 353–370, 1938.

Mahorner, H.: Sympathetic Nerve Blocks in Rehabilitation of the Injured Extremity. Report of Cases; and a Discussion of Causalgia. New Orleans Med. and Surg. J., **94**: 426–432, 1942.

Ochsner, A., and DeBakey, M.: Rational Therapy of Thrombophlebitis. New Orleans Med. and Surg. J., **94**: 173–178, 1941.

Patzer, R.: Personal Communication.

de Sousa Pereira, A.: Blocking of the Middle Cervical and Stellate Ganglions with Descending Infiltration Anesthesia. Technic, Accidents and Therapeutic Indications. Arch. Surg., **50**: 152–165, 1945.

DISCUSSION

Dr. J. E. M. Thomson, Lincoln, Nebraska: It is unfortunate that novocaine block of the sympathetics is not more generally recognized as a diagnostic and therapeutic aid in connection with those con-

ditions in which local circulatory insufficiency can be influenced by breaking the reflex arc. However, it must not be considered a panacea. The work of Ochsner and DeBakey and of others stimulated my experimental studies in this direction some years ago. These studies opened my eyes to the opportunities afforded for the therapeutic use of novocaine block in many conditions where I had previously not recognized its value.

This essay eminently calls attention to many of these conditions. My experience has been far more limited as to number of cases treated, but the gratifying observations with respect to block of the stellate ganglion in subdeltoid bursitis, posttraumatic swelling of the upper extremity, and certain subacute infectious or traumatic soft-tissue derangements of the elbow would lead me to be convinced of the authors' results in the other conditions enumerated.

It is well that attention has been called to the pitfalls of inexperience in the technique of performing the block; but, if one follows meticulously either the technique described by Ochsner and DeBakey or that of de Sousa Pereira, there is relatively little danger of complicating phenomena.

Our experimental work in animals showed that block of the stellate ganglion gave its maximum response for an average of fifty-six hours; and, with this as a criterion, we have observed that this maximum of effectiveness, as checked by thermocouple in the human, averaged about seventy-two hours. Therefore, we have the feeling that it is better to repeat the block after seventy-two hours than to chance having the pain and symptoms return to the region involved; for, if maximum effectiveness of the block can be maintained over a longer period, the possibilities of permanent relief are more probable.

DR. EDWARD L. COMPERE, CHICAGO, ILLINOIS: For about six years, I have been using a method similar to that described by Dr. Caldwell, Dr. Broderick, and Dr. Rose for injecting the muscles and the sympathetic ganglia of the neck. My experience does not include so many cases as have been reported by these authors. I have not had the opportunity of treating a case of phantom-limb pain. In most of my patients, some type of physiotherapy has been employed, in addition to the injections of procaine. The results which I have obtained have been approximately as satisfactory as those reported by these authors.

I do wish to raise one question. The immediate improvement in the circulation of an upper extremity and the relief of pain may be due to relaxation of a tight scalenus anterior muscle, into which some of the procaine has been injected. I have also observed beneficial results in my patients when there was evidence that the stellate ganglion had not been reached, as shown by complete absence of Horner's syndrome. The scalenus anterior syndrome is merely a reflex spasm of the muscle produced by any one of several conditions in the area of the cervical spine. Therefore, I am of the opinion that an effort should be made to relax this muscle by injecting a few cubic centimeters of the procaine into the muscle, as well as into the fascial spaces at the level of the transverse processes of the sixth cervical vertebral body, whence it may infiltrate downward to the stellate ganglion.

I have found it much easier to carry out the procedure of procaine injection with my patient sitting upright. On several occasions these patients have become quite faint, and it is most important that an assistant be ready to lend a hand, should syncope impend.

THE USE OF ILIAC BONE IN BONE-GRAFTING AND ARTHRODESIS

BY CAPTAIN C. A. LUCKEY AND LIEUTENANT COLONEL CARROLL O. ADAMS

Medical Corps, Army of the United States

In reconstructive work on war casualties, early surgical intervention is the treatment of choice in many cases of defective bone union. Many surgeons believe that, even if union is minimum, it will eventually be sufficient to withstand the stress and strain put upon it. This is frequently not the case. In war injuries a large portion of the bone may be lost, and union across a small bridge on one side of the fracture will never be sufficient. Therefore, early intervention is frequently to be preferred.

TREATMENT OF INJURIES

The types of non-union resulting from war injuries differ in several respects from those resulting from civilian injuries.

1. The patient may not have had the most desirable early treatment, due to circumstances. Thus the problem of infection must be dealt with in many cases.

2. Since most war wounds are not closed primarily, subsequent rapid closure of the wound, to prevent fibrosis and resulting joint limitation, is attempted.

3. In many instances the healed wounds must be repaired so that there is adequate soft tissue, before bone-grafting can be undertaken.

4. The non-union must be overcome. Tendon and nerve injuries, which are common complications of war wounds, must be repaired as early as possible; but frequently such repair must be delayed until after the soft tissue has been revised or even after the bone has been grafted.

Indications for Bone-Grafting

Bone grafts are indicated in the following conditions:

1. Where there is a loss of continuity, due to fractures that have not healed properly, and where there is resulting disability. If there is no disability, as in some cases of non-union of the clavicle, carpal navicular, and fibula, no treatment may be indicated, and bone-grafting should not be done. In rare instances in other bones, non-union causes few symptoms or none at all, and surgical treatment should not be advised.

2. Where there is minimum bony union, and the prognosis is for many months of disability while waiting for functional strength to return to the bone. Many of the bones have repeated fractures during this convalescent period.

3. In some fresh fractures where complications and delayed union are anticipated. The use of cortical tibial bone or a large piece of iliac bone, applied with screws, might hasten healing and serve as a form of internal fixation, instead of a plate.

4. In some cases in which an osteotomy is done to correct angulation that is causing functional disability. The bone graft is applied to make rapid bony union more certain, and to serve as internal fixation during the early convalescence.

5. To assist in arthrodesis in some cases.

Relation of Infection to Bone-Grafting

Formerly, six months was considered the minimum period which should elapse between the cessation of drainage and the institution of bone-grafting, but this was not considered adequate if there had been prolonged drainage. Three months is now considered an adequate waiting period after the cessation of drainage in many cases, for the following reasons:

1. Infections are cleared up much faster now by the use of repeated surgical attacks on wounds for the removal of sequestra and foreign material.

2. Wounds are closed more rapidly by the use of secondary closures, skin grafts, and the like.

3. The procedures mentioned and early bone-grafting are made possible by the use of the sulfonamides and penicillin, particularly penicillin.

Even though no sequestra have been visualized by roentgenogram, it is important to do a surgical exploration of the draining wound, especially if the drainage is not subsiding at a satisfactory rate. Not infrequently foreign bodies which are not radiopaque, such as bits of clothing, may be present in the wound and incite a persistent thick, purulent, foul, yellow discharge. This discharge should arouse suspicion concerning the presence of bits of clothing in the wound.

The minimum time between subsidence of infection and surgery is two months for skin work and three months for bone. The periods should be increased if prolonged drainage followed the initial injury. These periods are safe only if penicillin or the sulfonamides have been used before and after operation.

Early Closure of Wound

After deep drainage has ceased, the wound will heal rapidly by proliferation of granulation tissue. However, some of the extensive wounds can be closed more rapidly by applying a split-thickness skin graft to the granulating area. Saline dressings, changed every four hours, rid the wound of superficial infection in a few days and prepare the granulating bed for the skin graft. These grafts may not be completely successful in all cases; nevertheless, there is enough "take" to more than justify the procedure.

By getting the wound healed in this manner, one can speed up the date of bone-grafting, since this is calculated from the time the wound has healed. In addition, scar-tissue formation is diminished, which, in turn, means less joint limitation.

Adequate Soft-Tissue Coverage

Elimination of the more extensive soft-tissue defects is necessary before any bone reconstruction can be undertaken. Obviously, the smaller defects can be excised, and the skin edges can be undermined and approximated without undue tension. If the defect is slightly more extensive, a releasing incision, with shift of a ribbon flap to the opposite skin margin, will produce adequate closure. The defect produced by shifting the flaps is then covered with a split-skin graft. Normal skin, with its subcutaneous fat, now covers the area through which the surgical incision will eventually be made. Direct flaps from the abdomen provide excellent skin for the arm and hand. In the lower extremity, one can transfer a pedicle from one leg to the other. These pedicle grafts may be transferred either directly or by the delayed method. The method used is determined by the length of the pedicle and the appearance of the flap as it is elevated gradually. Direct flaps can also be transferred from one thigh to the opposite leg. Usually the pedicle of the graft is detached three weeks from the time the graft is done.

If the defect is quite extensive, a tubed pedicle graft may be necessary. The authors have done all types of soft-tissue coverage not necessitating the making of a tube. In Army practice, tube grafts have been done at Plastic-Surgery Centers. The value of complete coverage of all the open areas at the time the pedicle graft is done needs special stress. Reference is made especially to the donor site of the pedicle graft and also to that part of the underside of the pedicle which does not come into contact with the recipient area. If the denuded areas are not covered with a split-skin graft, infection and fibrosis result. Frequent dressings are then necessary and the bone surgery must be delayed. When split-thickness grafts are used to cover the donor site of the pedicle, a completely closed and surgically clean wound is the result.

In non-union due to an old compound fracture, many bacteria undoubtedly are im-

bedded in the overlying scar tissue. While imbedded in the scar, they are dormant. When the scar is incised surgically, infection may result from activation of the dormant bacteria. This accounts for some of the flare-ups of infection after operation. In many instances the scar should be excised a few weeks before bone-grafting, so as to avoid this complication. Even though the scar does not appear troublesome, excision prior to bone-grafting may avoid a flare-up of infection.

At the time of scar excision, one must anticipate the incision to be made during bone-grafting. By planning ahead, one can sometimes avoid placing the incision directly over superficial bone and putting the skin under undue tension.

PHYSIOLOGY OF BONE TRANSPLANTS

There is rarely non-union in spongy bones such as the ilium, the bodies of the vertebrae, and the small bones of the hands and feet. The only exception is in certain bones of the body where part of the bone may become non-viable, due to interruption of its blood supply by trauma. Cancellous bone having thin trabeculae, extensive contact with tissue fluid, and an extensive blood supply is rapidly replaced when used as a transplant; therefore bony union is rapid.

Cortical bone is very specialized. Its density delays the firm adherence of callus. The vascularity of the cortex is minimum; so the new bone callus at the fracture site must be produced and nourished by an ingrowth of new vessels, sometimes from a considerable distance.

Phemister [16,19] has observed the changes which bone undergoes when transplanted. He states that, with the exception of a few cells on the surface, the greater mass of cells die. Subsequent changes in the graft then depend upon its location: If it is in a useful position, progressive changes take place; if in a useless location, retrogressive changes occur. Callus then forms at either end to help unite the transplant to the fragments. Creeping substitution of the dead cortex gradually occurs by the ingrowth of capillaries, with dilation of the haversian canals, absorption of the old bone, and deposition of new bone in its place. The dead bone is absorbed by mononuclear and occasional polymorphonuclear osteoclasts. New bone is then deposited on parts of the walls of the dilated canals in successive layers. Once the graft has become fixed at both ends, the tissue between the fragment ends no longer remains static; but it responds to functional stress and strain and ossification occurs. Likewise the graft will become hypertrophied, depending upon the force transmitted through it.

After strength has increased so that it satisfies the demands of function, remodeling of the bone takes place. Eventually a new medullary cavity is formed, and the excess bone around the old site of non-union is absorbed, until the final contour is not unlike the original [17,20].

BONE USED IN GRAFTING

Local Bone

Bone taken from the region of the fracture may be used as a sliding type of inlay graft. It may also be cut into small chips and laid back into the slot from which it was removed.

Multiple drilling with a small drill is one form of local graft, for it produces many small particles of bone at the fracture site, in addition to opening up new channels for the invasion of this area by new blood vessels.

Tibial Bone

Several forms of graft can be obtained from the tibia. From the mid-shaft, dense, heavy cortical bone can be obtained. From the upper part, bone can be obtained which has a thin cortical layer and considerable underlying spongy bone.

Fibular Bone

The fibula can be split and used for onlay grafts, or it can be left whole and used as a "dowel". Removal of the upper or middle portion of the fibula causes the patient no disability.

Bone from Ribs

Rib material offers a readily available source of bone for grafting. In grafting long bones, it has no advantage over iliac bone. It has been used to advantage in doing spinal fusions on cases of scoliosis with marked deformity of the rib cage [5]. It has also been used in grafts of the mandible. The authors have had no experience with rib grafts.

Iliac Bone

In recent years the use of cancellous bone has been emphasized by numerous workers. Ghormley has stressed the value of cancellous bone removed from the region of the posterior superior spine of the ilium, in performing lumbosacral fusions. Abbott and his coworkers have stressed the wide use to which iliac bone may be put in bone-graft surgery. Mowlem used cancellous bone chips to bridge large gaps in the long bones, where there was loss of bone substance and no bony contact whatsoever between the fragments. He stated that cancellous bone was being used almost to the exclusion of cortical bone.

The advantages of cancellous bone over cortical bone have been stressed repeatedly in the past. The chief advantage is that union and replacement are more rapid, due to the porous nature of the bone. Secondly, strips of iliac bone can be placed across the site of non-union with a minimum amount of dissection and stripping of periosteum. In addition, there is no fear of injury to the donor site, as there is when the tibia is the donor. Usually bone from the anterior part of the wing of the ilium can be used. In those cases where the patient is placed prone upon the operating table, however, the posterior portion of the ilium is utilized.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Before operation.

Fig. 1-B: After operation. Non-union of tibia treated by removing bone across fracture site, cutting graft into small chips, and reinserting the chips in the slot. Replacement of bone is rapid, since there is no large transplant, but rather multiple small chips. (*Letterman General Hospital Photographic Laboratory.*)

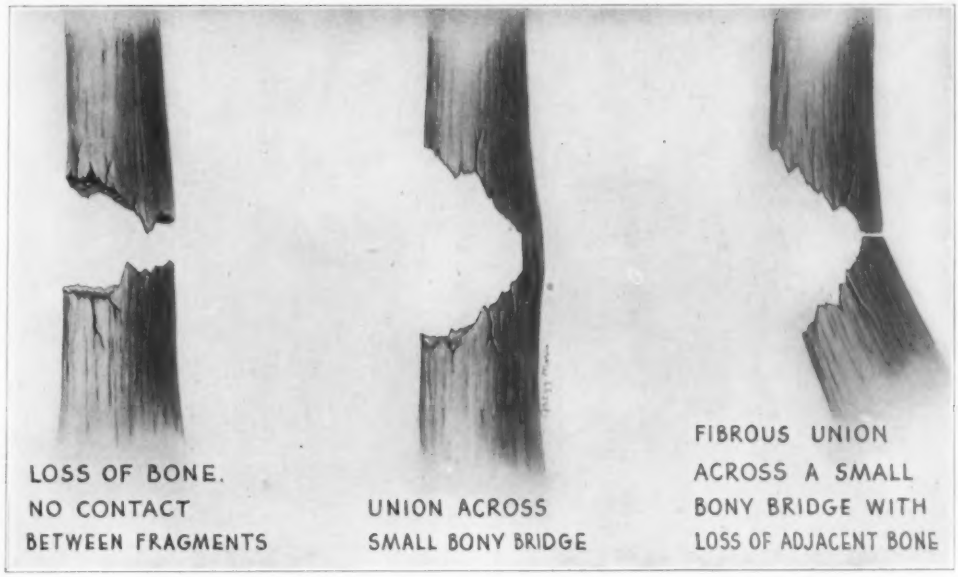

FIG. 2

Types of non-union encountered.

OPERATIVE TECHNIQUE

The type of graft used and the method of fixation vary with the nature of the non-union and with the bone involved. When reduction is difficult to maintain, the authors employ the massive onlay graft described by Henderson. Sliding grafts [11] and inlay grafts [3] have been employed in isolated instances. Usually the onlay graft is preferable to the inlay type. In cases suitable for a sliding graft, the choice has sometimes been to remove the graft, cut it up into chips, and replace it along the groove from which it was removed (Figs. 1-A and 1-B).

Bone drilling was not employed by the authors. Those cases suitable for drilling are

FIG. 3-A

FIG. 3-B

Fig. 3-A: Before operation.

Fig. 3-B: After operation. Defect corrected by insertion of multiple iliac strips.

FIG. 4-A

FIG. 4-B

FIG. 5

Fig. 4-A: Before operation.

Fig. 4-B: After operation. Humerus, with motion at site of non-union, treated by inserting multiple iliac strips. No internal fixation was used; position was maintained by plaster cast. Occasionally cast must be wedged to correct angulation. (*Letterman General Hospital Photographic Laboratory.*)

Fig. 5: Two-inch defect in ulna has been grafted with iliac bone. (*Letterman General Hospital Photographic Laboratory.*)

also suitable for iliac grafts or chip grafts, and the latter methods are more certain of bringing about bony union.

Osteoperiosteal grafts are rarely used except in an occasional joint arthrodesis, as described by Delangenière and Lewin. Iliac grafts have been more suitable. Intramedullary bone was used, as a rule, only in metacarpal grafts.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Before grafting.

Fig. 6-B: After grafting. Method of fixation of iliac graft in non-union of ulna. Iliac graft was readily applied and held by turned-up cortex of recipient bone. Union was rapid. (*Letterman General Hospital Photographic Laboratory.*)

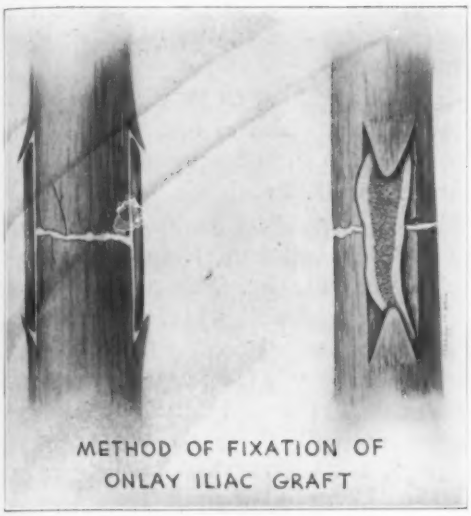

FIG. 7

FIG. 8

Those cases in which union takes place across a small bridge of bone (Figs. 2, 3-A, and 3-B) and those in which there is contact between two bone fragments, even though it is minimum and the union is by fibrous tissue (Figs. 4-A and 4-B), are ideal cases for the use of cancellous bone from the ilium. If the non-union is such that the position of the fragments could be maintained properly with a plaster cast after surgery, one should not hesitate to use cancellous bone. In some cases, wedging of the cast is necessary after operation to obtain the necessary alignment. In some of the long bones, such as the radius and the ulna, large gaps can be bridged with strips from the ilium and maintained with screws (Fig. 5). It is believed that iliac bone could be used more extensively in non-union of the long bones, especially the radius or ulna, where there is loss of bone substance for some distance. By cutting a large graft from the ilium, one can apply it in onlay fashion and use screws for fixation and maintenance of reduction, just as with cortical bone.

In those cases with a fairly large bone defect, in which reduction cannot be maintained by the iliac grafts and cast alone, a large graft of tibial bone can be applied, in addition, in onlay fashion; and the position of the fragments can be maintained with screw fixation. The iliac graft then serves to fill the defect. Only very rarely has a metal plate been substituted to maintain reduction.

Horwitz and Lambert have used a metal plate for fixation and then applied grafts around the site of the non-union. A cortical graft is more physiological and, if properly immobilized in plaster, is not liable to fracture. The authors have used a plate only, combined with a graft occasionally, in non-union of the upper part of the femur, where it was felt that the stress was more than a strip of tibial bone could withstand.

A number of patients have been seen who were treated elsewhere by plating and the introduction of iliac grafts. In many of these cases the plate had taken all of the stress and strain, and as a result the iliac grafts had become absorbed. This has been observed most frequently in cases in which there has been loss of bone substance. With this observation in mind, the authors feel that, when internal fixation is needed, a tibial graft plus iliac strips is more physiological and much more likely to produce union than is the procedure of plating and insertion of iliac grafts.

The use of dual plates and grafts around the plates, as described by Key, is seldom, if ever, indicated. Patients have been seen in whom dual plates had been applied for fresh fractures in the tibia. When these patients were later seen by the authors, the plates had to be removed. When iliac grafts are used, rigid fixation of the grafts is not a problem.

Plaster immobilization has always been sufficient (Figs. 6-A and 6-B). The use of pla and screws before the grafts are applied calls for considerable stripping of the soft tiss and periosteum, which, in turn, means a delay in healing.

The size and shape of the iliac grafts and the means of fixation vary with the natu of the non-union and also with the bone involved. The method of removal of the ili strips has been described by Abbott. In some instances the authors applied them in onl fashion, chiseling away only a portion of the recipient cortex. In other instances the cort is partially elevated at one end and attached at the other. The attached portion of t cortex is then used to hold the graft in position (Figs. 6-A, 6-B, and 7). In other cases t grafts are wedged into slots produced by an osteotome (Fig. 8). This method preven excessive stripping of the periosteum and is especially applicable where the bone of t recipient area is quite osteoporotic or naturally cancellous, since it is easy to produce a sl in these areas. In still other cases the strips are intramedullary in one fragment and appli in onlay fashion on the adjacent fragment. This procedure is used especially in cases which the non-union is in the vicinity where the bone normally flares, such as at the end some of the long bones. A combination of the methods described is used in most case Chips of cancellous bone are usually placed about the site of non-union.

Many surgeons believe that rigid fixation is essential for rapid bony union. Murra has been a strong advocate of rigid fixation of the graft. Phemister,[18] on the other han has maintained that, if the graft can be held adequately by soft tissues, screw fixation unnecessary, provided a plaster cast will immobilize the fragments well. In a number instances of unstable fibrous non-union, iliac grafts have been applied across the site non-union, as described, and immobilization has been maintained with only a plaster cas Union was rapid in every case. If the soft tissues will hold the graft in position and if re duction can be maintained by a cast alone, screw fixation of the graft is not essential. O the other hand, if reduction is difficult to maintain and if the soft tissues will not hold th graft in a satisfactory position, as is frequently the case in non-union of the radius an ulna, internal screw fixation should be used.

As a rule the scar tissue has been curetted out from the site of non-union. In som instances there was danger of a flare-up of an old infection, so the scar was left intact only partially removed; union progressed without delay in each instance. Phemister[18] has shown that removal of the scar tissue is not necessary for the establishment of bon

FIG. 9-A

FIG. 9-B

Fig. 9-A: Before operation.

Fig. 9-B: Subtalar arthrodesis was performed after the method described by Gallie, but using iliac bone instead of tibial bone. Iliac graft is faintly visible. (*Letterman General Hospital Photographic Laboratory.*)

union. Once the graft has been united at both ends, the intervening tissue ossifies, as described previously. Many authors advocate complete removal of the fibrous tissue from the site of non-union [4,15].

Minimum soft-tissue dissection about the site of non-union is most important. Haldeman has shown experimentally that excision of the periosteum from the ends of the bone fragments delays callus formation and ossification. Phemister [20] has observed that excessive periosteal stripping leads to a delay in ossification. The authors have done a minimum amount of soft-tissue dissection in these cases. When using iliac bone, one frequently is able to insert the grafts in slots or in onlay fashion by raising a portion of the cortex with its intact periosteum. Thus there is a minimum degree of interference with the periosteum.

FIG. 10

USE OF ILIAC BONE IN ARTHRODESIS

Strips of cancellous bone from the ilium have been used very satisfactorily in arthrodesis of the wrist, knee, and subtalar joints. In subtalar fusions, the method described by Gallie has been used. His original description advocated a posterior approach; removal of a truncated wedge of bone from the subtalar joint; and insertion of two pieces of tibial bone, cortex to cortex, into the defect. Instead of using tibial bone, the authors employ cancellous bone from the region of the posterior superior spine of the ilium (Fig. 9-B); in seven cases fusion has been by this method. Roentgenograms of the subtalar joint, taken soon after arthrodesis had been carried out in this manner, show very little change from those taken before operation; therefore, one must be on guard when interpreting these films. Replacement of the iliac transplant is more rapid than is replacement of the tibial transplant employed by Gallie.

Fusions of the wrist were done, using iliac bone, as described by Abbott, Saunders, and Bost. The technique is not difficult and excellent results have been obtained.

In war injuries about the knee, not infrequently the patella and most of one femoral condyle may be shot away. Arthrodesis of such a joint presents a problem, because joint resection and removal of the remaining condyle to obtain maximum bony contact produce undue shortening. To arthrodese such a knee, we have resected the joint and bridged the gap where the condyle is absent, as well as where the tibia and femur come into contact with iliac bone (Fig. 10). Three or four strips of iliac bone are driven into a slot across the joint anteriorly (Fig. 11-B). When firmly wedged into a slot, these iliac strips provide immobilization and, more particularly, aid fusion. By immobilizing the joint with pins, the grafts can be inserted with relative ease. The insertion of iliac grafts is justified in knee arthrodesis, even though both condyles and the patella are present. Knee fusions frequently are slow, and anything that will speed up the process is time saved for the patient. The method employed in knee arthrodesis is shown in Figure 10.

RESULTS

The total number of bone grafts done for non-union and the donor bone used are indicated in Table I.

TABLE I

BONE GRAFTS FOR NON-UNION

Bone Grafted	Donor Site				
	Local (Sliding or Chip Grafts)	Tibia	Ilium	Radius or Ulna	Total
Clavicle		1			1
Humerus		7	2		9
Radius		5		1	6
Ulna	4	8	3		15
Radius and ulna at same time		3			3
Navicular			2	2*	4
Metacarpal		12		13	25
Phalanges		3		4	7
Femur					
Neck	3				3
Upper portion	2	6	7		15
Mid-portion		4	5		9
Lower portion		4**	7		11
Tibia					
Upper portion		2†	7		9
Mid-portion	2†	7	6		15
Lower portion	3	6	6		15
Medial malleolus		16			16
Metatarsal		1			1
Totals	14	85	45	20	164

* Cancellous portion used.
** Tibial and iliac bone used in one of these cases.
† Chip grafts (Cowan's method).

As a rule, the iliac grafts were done late in the series. Experience has revealed the wide range in which iliac grafts can be used, and thus the authors are now using them more extensively than previously. At present, many metacarpal grafts are being done with iliac bone, whereas previously the ulna or tibia was used as the donor site.

Tibial bone was used rather frequently in arthrodesis, particularly in fusions of the ankle, tibiocalcaneal fusions, and those of the tibia, talus, and calcaneus, because of its ease of accessibility and the support it produces (Table II). The use of iliac grafts in arthrodesis has already been discussed.

Of the 228 cases operated upon (by graft or arthrodesis), there was a flare-up of latent infection in twenty-two instances (Table III). *However, union was obtained in seventeen of these cases in spite of the infection.* Most of the flare-ups were either mild or moderate. In these seventeen cases the drainage either subsided spontaneously or, in a few cases, a few small sequestra were removed from the wound, after which drainage eventually ceased.

The histories revealed that not infrequently the flare-ups following surgery were in individuals who had had no drainage for six months prior to surgery. In most cases three months after subsidence of drainage is a safe time to proceed with bone-grafting. However, a longer delay will do no harm. Since none of the donor sites became infected, and since all of the postoperative infections occurred in association with old compound fractures, the infections were considered to be the result of flaring up of a dormant process in the wound, rather than the introduction of new bacteria at the time of operation.

Failures of arthrodesis or bone-grafting occurred in thirteen cases (Table IV). A few of the cases listed were presumptive failures and may be successful eventually. These patients were transferred to other hospitals, so that we were unable to follow them sufficiently long to determine the ultimate outcome; therefore they are listed with the failures at this time. There were five failures due to infection; one of these patients was not oper-

TABLE II

ARTHRODESIS

Arthrodesis	Donor Site				Total
	Local or None	Tibia	Ilium	Radius	
Spine	2		2		4
Shoulder		2			2
Wrist		1	3		4
Metacarpophalangeal and interphalangeal	4			3	7
Knee			2		2
Ankle		5	1		6
Ankle and subtalar		4			4
Triple arthrodesis	9				9
Subtalar			7*		7
Tarsal	1	3			4
Interphalangeal	11	1			12
Tibiocalcaneal fusion (following astragalectomy)		3			3
Totals	27	19	15	3	64

* After method described by Gallie, but using iliac bone.

TABLE III

INFECTION IN CASES OF GRAFT AND ARTHRODESIS

Degree of Infection	Donor Site			Results	
	Ilium	Tibia	Other Locations	Failure	Solid Bony Union
Mild	5	4	2	0	11
Moderate	3	2	1	1	5
Severe	1	3	1	4	1
Totals	9	9	4	5	17

ated upon by the authors at the time of the flare-up. One of these five cases was an arthrodesis, and the other four were cases of bone-grafting.

One of the cases of infection occurred in an attempted arthrodesis of the distal joint of the large toe. Progress was slow following infection, so that the distal end of the toe was amputated; the patient suffered no disability. In another case listed as a failure, iliac strips were laid in a granulating wound and the skin margins were brought together over the graft. Although it is sometimes advocated, we feel that this procedure should be discouraged. Infection, even though mild, is almost certain to result and to persist for some time.

Another failure was in an attempt at arthrodesis of the interphalangeal joint of the large toe. Originally, the cartilage was removed and the position was maintained by placing a Kirschner wire through the two phalanges. At the second operation a tibial peg was driven across the joint. In a similar case in our series, fusion was very slow when only the cartilage had been removed. Since the graft adds very little to the difficulty of the operation, the authors feel now that this should be done originally in all cases of this kind.

A second graft of the phalanx was done in two cases. In one the graft was solid, but the operation was repeated to correct a faulty position. In the other case a tendolysis was

FIG. 11-B

FIG. 11-A

Fig. 11-A: Before operation.
Fig. 11-B: Arthrodesis of knee has been performed, using iliac strips to bridge joint.

TABLE IV

FAILURES OF BONE-GRAFTING AND ARTHRODESIS

Patient	Bone or Joint Involved	Donor Site		Infection	Remarks
		First Graft	Second Graft		
D.N.	Ulna	Local chips	Tibia	None	Excellent result following second graft.
G.T.	Ulna	Tibia	Tibia	None	Original graft fractured and pseudarthrosis developed.
W.B.	Phalanx	Ulna	Tibia	None	Regrafted, because of faulty position. Original graft solid, however.
J.R.	Phalanx	Ulna	Radius	None	Tendolysis done two months after first operation; bone not solid, so additional small graft done. With more time this would probably have united without additional surgery.
L.H.	Femur	Tibia	Not done	Present	Some mild angulation. Not able to follow patient long enough to determine if solid. When last seen, union was progressing.
W.M.	Femur	Tibia	Ilium	None	Original graft fractured. At second operation the old tibial graft was replaced and iliac strips were used in addition. Union progressing when patient was last seen.
L.P.	Tibia	Tibia	Tibia	Present	First graft done elsewhere; failure due to infection. After second graft, some wound separation.
A.L.	Tibia	Ilium	Not done	Present	Iliac strips laid in granulating wound and skin brought over grafts. Wound separated.
H.G.	Ankle	Tibia and fibula	Not done	None	Satisfactory clinical result, but no bony union.
B.K.	Ankle	Fibula	Not done	None	Satisfactory clinical result, but no bony union.
I.M.	First metatarsal	Tibia	Not done	Present	Drainage following surgery, so graft removed.
W.W.	Inter-phalangeal joint of large toe	None	Not done	Present	Tip of toe amputated eventually; no disability of foot.
M.L.	Inter-phalangeal joint of large toe	None	Tibia	None	Originally, cartilage removed and immobilization obtained by Kirschner wire. At second operation, tibial peg driven across joint.

erformed, two months after the graft. Motion was noted at the time of this operation, so hat an additional small graft was inserted. More time would probably have brought about nion.

SUMMARY

Elimination of infection by early and frequent surgical intervention is most important the treatment of infected compound fractures. Early coverage of the wound aids materially in two ways: First, as soon as the wound has been covered with skin and scar tissue, roliferation ceases; thus there is less soft-tissue damage and less joint stiffness. Second, one-grafting can be done at an earlier date, due to the fact that infection has been liminated early.

The soft-tissue coverage must be adequate before grafting is done. Unless split-skin rafts have considerable subcutaneous fat and muscle between them and the bone, they will ot withstand the strain when exposure is made through them. Therefore, pedicle grafts ust be used in many instances to replace poor skin.

With the use of penicillin, bone-grafting can be done three months after the cessation drainage, if all other factors are favorable.

The type of bone graft varies with the circumstances. Whenever possible, iliac grafts ould be used, since they are usually applied easily and replaced rapidly. Foreign mate-

rial for internal fixation is necessary only when the fragments and the graft will not remain in position without internal fixation.

Iliac grafts aid materially in arthrodesis, particularly of the wrist, knee, and subtalar joints, and the small joints of the hand. The authors have had no experience in employing iliac bone in the stabilization of other joints.

REFERENCES

1. Abbott, L. C.: The Use of Iliac Bone in the Treatment of Ununited Fractures. Am. Acad. Orthop. Surgeons, Lectures on Reconstruction Surgery, pp. 13–22. Ann Arbor, Michigan, Edwards Bros. Inc., 1944.
2. Abbott, L. C.; Saunders, J. B. deC. M.; and Bost, F. C.: Arthrodesis of the Wrist with the Use of Grafts of Cancellous Bone. J. Bone and Joint Surg., **24**: 883–898, Oct. 1942.
3. Albee, F. H.: Original Surgical Uses of the Bone-Graft. A Report of Two Hundred and Fifty Cases. Surg., Gynec., and Obstet., **18**: 699–718, 1914.
4. Armstrong, J. R.: Bone-Grafting in the Treatment of Fractures. Baltimore, The Williams and Wilkins Co., 1945.
5. Bickel, W. H.; Hinchey, J. J.; and Clagett, O. T.: Treatment of Severe Scoliosis with Rib Resection and Immediate Fusion of Vertebrae. Proc. Staff Meet., Mayo Clin., **19**: 401–404, 1944.
6. Delangenière, H., and Lewin, P.: A General Method of Repairing Loss of Bony Substance and of Reconstructing Bones by Osteoperiosteal Grafts Taken from the Tibia. 273 Observations. Surg., Gynec., and Obstet., **30**: 441–447, 1920.
7. Gallie, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis. J. Bone and Joint Surg., **25**: 731–736, Oct. 1943.
8. Ghormley, R. K.: Low Back Pain. With Special Reference to the Articular Facets, with Presentation of an Operative Procedure. J. Am. Med. Assn., **101**: 1773–1777, 1933.
9. Haldeman, K. O.: The Role of Periosteum in the Healing of Fractures. An Experimental Study. Arch. Surg., **24**: 440–450, 1932.
10. Henderson, M. S.: Nonunion in Fractures: The Massive Bone Graft. J. Am. Med. Assn., **81**: 463–468, 1923.
11. Hoglund, E. J.: New Method of Applying Autogenous Intramedullary Bone-Transplants and of Making Autogenous Bone-Screws. Surg., Gynec., and Obstet., **24**: 243–246, 1917.
12. Horwitz, T., and Lambert, R. G.: Treatment of Ununited Fractures of Long Bones. A Method Combining Grafting and Internal Fixation. J. Bone and Joint Surg., **27**: 637–644, Oct. 1945.
13. Key, J. A.: Dual Plates for Internal Fixation in Non-Union of Fractures. J. Bone and Joint Surg., **27**: 632–636, Oct. 1945.
14. Mowlem, R.: Cancellous Chip Bone-Grafts. Report on 75 Cases. Lancet, **2**: 746–748, 1944.
15. Murray, C. R.: The Basic Problems in Bone-Grafting for Ununited Compound Fractures. J. Bone and Joint Surg., **26**: 437–442, July 1944.
16. Phemister, D. B.: The Fate of Transplanted Bone and Regenerative Power of Its Various Constituents. Surg., Gynec., and Obstet., **19**: 303–333, 1914.
17. Phemister, D. B.: Repair of Bone in the Presence of Aseptic Necrosis Resulting from Fractures, Transplantations, and Vascular Obstruction. J. Bone and Joint Surg., **12**: 769–787, Oct. 1930.
18. Phemister, D. B.: Splint Grafts in the Treatment of Delayed and Non-Union of Fractures. Surg., Gynec., and Obstet., **52**: 376–381, 1931.
19. Phemister, D. B.: Bone Growth and Repair. Ann. Surg., **102**: 261–285, 1935.
20. Phemister, D. B.: Rapid Repair of Defect of Femur by Massive Bone Grafts After Resection for Tumors. Surg., Gynec., and Obstet., **80**: 120–127, 1945.

FACTORS INFLUENCING CALLUS FORMATION IN OPEN FIXATION OF FRACTURES *

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The object of this paper is to consider the factors which, due to the surgeon's operative interference, may influence the speed of formation of callus and its quality and quantity. Only the factors related to surgery are considered, and not the nature of trauma, the location of the fracture, the state of health of the patient, or his age. A presentation of the still widely discussed theories on the histology and biology of bone formation is not included. Due to circumstances, proper illustrations and statistical data are, unfortunately, lacking.

THE SIGNIFICANCE OF THE TIME OF OPEN FIXATION

The surgeon may operate upon fractures at different intervals after their occurrence. The time of operation may have marked influence on the callus, and will be considered in two groups of cases: cases of fresh fracture and those of old fracture.

Fresh Fractures

In the group of fresh fractures are included all fractures in which the process of callus formation has not been definitely concluded.

The histological and biological processes which take place at the site of the fracture, before healing can occur, are well known: the resorption of dead tissues; the organization of the soft parts, including the hematoma, into a network of fibrin and young connective tissues; the mobilization of mineral salts from the fragments; and especially the building of a new network of blood vessels, which will guarantee the transportation of the needed chemical supplies. This important transformation, without which the solid union of bone *cannot* take place, occurs in an acid medium and requires from eight to fifteen days. Only after its completion does the pH become alkaline and allow the precipitation or the fixation of mineral salts.

From these well-established facts, one can arrive at three important deductions, which are amply confirmed by observations:

1. If the surgeon decides upon open fixation, and if the time can be chosen, the most favorable moment will be as soon as possible (emergency operation) after the fracture has taken place. In this way the dead tissues will be removed surgically; the periosteum and the soft parts will be replaced immediately in their anatomical positions, close to the site of the fracture; and an optimum supply of blood will be assured. There will be a minimum chance of infiltration of the muscles, which will give them a quicker restoration of function; this, in turn, means better circulation around the fracture. The delicate building up of the pre-osseous connective tissue will take place under the best anatomical and physiological conditions; and, finally, if the operation has been technically perfect, there will be no need of external immobilization. If external immobilization can be abandoned, an optimum restoration of circulation will result from function of the muscles and joints. Under these circumstances, the callus will be of minimum size (with very little bridging inside or outside the cortex); it will develop at maximum speed, for the blood supply will be good; and it will be in an optimum location (in the line of fracture).

2. Open fixation which is performed between this emergency period and approximately the fifteenth day after fracture necessitates operating through infiltrated muscles, the destruction of the delicate formation of young connective tissue and of the new vascu-

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larization, and the stirring up of local mineral metabolism. Nature's work is destroyed i its making and it must be started again, with a new response to a new trauma. Open fi tion performed at this time—thus *delayed*—usually gives rise to more extensive callus a slows down the process of repair.

3. Operating after the period of restoration (eight to fifteen days after fractur means operating in an alkaline medium and destroying connective tissue which is alrea differentiated. It interferes with the mineral metabolism at a time when minerals a already being deposited in the new bony structure. It implies the destruction of the n vascular network. It is more or less like operating in scar tissue. It retards still more t formation of callus, and may even impair seriously the formation of new bone. It tak eight or ten months for the line of fracture to disappear in a retarded or late open fixatio whereas it takes only four or five months when fixation is done as an emergency measu

Old Fractures

Included in this group of cases are the ununited fractures with more or less demine alization, and the malunited fractures. In both types of cases, the outstanding featu might be called "inertia" of the bone.[17] This lack of response to surgical interferen varies greatly from case to case and depends mostly upon the blood supply. It also co pels the surgeon to use artificial means of providing new supplies of mineral, such as bo grafts; and technical procedures, which will be described later.

A few observations which may be significant in the development of callus in old fra tures are as follows: (1) The formation of callus is influenced by the addition of fre bone and also by the stirring up of bone at the site of the fracture. (2) The developme of callus is often extremely slow, sometimes almost non-existent; means of stimulati bone formation are still being investigated. (3) In delayed union or in non-union of diaphysis, one fragment is always more demineralized than the other. (This is of technic importance.) The fragment in which demineralization is greater usually gives rise aft operation to more bone than the other fragment. (4) In fractures of the two bones of o limb, one of the bones is usually more demineralized than the other. (5) Spontaneous d mineralization of the corresponding bone of the other side has been observed.

THE IMPORTANCE OF REDUCTION

If open fixation of a fracture has been performed at the optimum time, the reductio of the fragments will have a bearing on the rapidity of callus formation, the shape an the amount of callus.[3]

Rapidity of Callus Formation

The rate of callus formation is influenced greatly by the coaptation of the fragment The more nearly the fragments are in contact, the quicker the line of fracture disappear This has been observed in many cases.

In plating the two bones of the forearm, there is always a slight difference in coapta tion between the two bones, in spite of the best technical ability; this is emphasized in ol fractures if the plating is done after resection of the four ends of the fragments. The bon in which the reduction is better will almost always heal first.

Three patients with similar non-union of the radius were operated upon by the auth on the same morning. The rate of disappearance of the line of fracture in these case coincided exactly with the degree of coaptation. Another patient was operated upon fo non-union of both tibiae. Both legs were in a similar condition; both were operated upon b the same procedure, external fixation. The postoperative course was uneventful on bot sides. One side showed a perfect coaptation of the fragments; the other side showed separation of about two millimeters. The first side healed clinically and, according to th roentgenographic examination, exactly twice as fast as the other side.[12]

The Shape of the Callus

The shape of the callus also varies with the perfection of the reduction. This was noted especially in the cases just mentioned. If the two cylinders of compact bone are in perfect contact, bone usually forms between them and very little forms on the outside or the inside. If there is a space between the two cylinders, new bone will form first around the line of fracture (bridging) and only later between the layers of cortical bone. Theoretically, and often practically, the amount of bridging depends upon the amount of separation of the fragments and is proportional to it.

Amount of Callus

The amount of callus is also influenced by the degree of reduction. The poorer the reduction, the larger the callus.

THE INFLUENCE OF FIXATION

If a fracture has been operated upon at the optimum time and the reduction has been perfect, the rapidity of callus formation, its quality, and its quantity will depend upon the degree of fixation of the bone fragments. The perfection of fixation is much more important than the time of operation and the perfection of the reduction. Fixation depends almost entirely upon the surgeon, the method he uses, the type of material he uses, and his technique.

A few methods will be enumerated which do not give adequate fixation, and then one will be mentioned which does give fixation:

Insufficient Fixation Due to the Method

External fixation, which was first used by Malgaigne during the last century, was later perfected and was officially presented by Lambotte in 1902. Since then, it has been the subject of much experimentation and discussion. The method consists in fixing a fracture of a diaphysis by pins or screws, held together outside the body by a bar. For mechanical reasons, the two proximal screws must be inserted as near as possible to the line of fracture and the two distal screws as far as possible from it. In spite of this mechanical device, a certain degree of mobility remains, even when the reduction is perfect. Surgeons who use this method know that bony union is delayed because of the lack of complete immobilization. For this reason, and because of the danger of infection, many surgeons have abandoned the method. External fixation, however, still remains the best method of treatment of bad compound and comminuted fractures with extensive laceration of the soft tissues.[13,15]

When both bones of the forearm have been fractured, a plate should be applied to each. Surgeons still apply a plate to one bone, however, and are satisfied to leave the other bone alone if the fracture has been well reduced. They are aware that the procedure is insufficient, and therefore they always add a plaster-of-Paris cast. In spite of the cast, the bone which is not held by a plate will always show delayed union, and sometimes even nonunion. This is definite proof of the important effect of fixation on callus formation.

In spite of good reduction and strong plating, the results of open reduction of fractures of the tibia have not been satisfactory, because of a slight mobility due to sheering. The author therefore decided upon the intramedullary placement of a small bone peg at the line of fracture, and later advocated plating of the fibula.[8]

In an open fixation, a surgeon's technique must be such that complete immobilization of the fragments will be achieved. In that respect, cross fixation through the line of fracture, added to plating (a method which we probably owe to Clay Ray Murray), has been a valuable contribution to fracture surgery. By the quick formation of callus, the rapidity of disappearance of the line of fracture, and the optimum amount of bone formation, this method has proved that fixation is the most important of the factors which may influence callus formation in open fixation of fractures.

Insufficient Fixation Due to the Type of Material

A surgeon may perform an open fixation of the femur with plating. In spite of a pe fect technique and an uneventful postoperative course, without fever or pain for days weeks, the following symptoms may suddenly develop: slight rise in temperature, slig deformity of the thigh, a moderate swelling, and a moderate amount of pain. Under the circumstances, the surgeon may be sure that the plate is either bent or broken.

If the plate bends, mechanical insufficiency is usually the cause. The amount of met inserted at open fixation does not matter. For the femur, a plate should be used which at least two millimeters thick and not perforated at its middle portion, which would be the line of fracture.[9] The addition of cross fixation will help greatly to prevent bendin If one attempts to correct the bend under anaesthesia and to immobilize the thigh in plaster-of-Paris cast, the callus will usually develop quickly and become rather large. sort of "reactivation" takes place at the site of fracture.

If the plate breaks, the complication is more serious. Breaking of the plate is alway due to a defect in the metal. It may have been tempered for the sake of solidity, which a mistake. It may contain impurities or it may have been rendered brittle by manipulation most often by hammering or by constant vibrations.

The author's experience included a series of broken plates in consecutive cases. Th metal used was Krupp's stainless steel V–2A, which had previously given satisfaction. A abnormal reaction of bone against certain parts of the plates, mostly at the tips of th screws, was noticed. All the plates came from the same stock. An examination of the ste was made. The crystals were regular and homogeneous, which proved that there had bee no fault in the manufacture; but many microscopic specks were present between the crys tals, and these specks were suspected to be impurities of carbon or high-carbon stee which probably provoked electrolysis.

Insufficient Fixation Due to Technical Factors

A few of the most important examples are as follows:

Loosening of Screws: One or more screws on one fragment may become loose, an slight or even serious complications may result. The callus formation is slowed down be cause of the lack of immobilization. Formation of extra bone may occur around the loos screws and also around the loose end of the plate. There are several possible causes of thi troublesome complication:

1. The drill may have been a trifle too large, and the screw may have moved in its canal. A space would then exist between the surface of the screw and the surface of the canal.

2. The drill may have been a little too small, and the screw may have been inserted under pressure, especially if a mechanical screw driver was used. This abnormal pressure would cause resorption of bone.

3. The size of the drill may have been perfect, but the bone may have been hard. This is often true of old fractures. Here, also, the screw may have been inserted under pressure. In certain instances, the self-tapping screw is insufficient, because the tap end is too soft. A tap should be made of hard steel, preferably of tempered steel. Perfect tapping will allow the screw to reach the opposite cortex in line with the exact point of penetration and in the right direction. In a large bone, the self-tapping screw might make its own thread through the first cortex in a slightly oblique direction; it then would reach the second cortex at the wrong point and in the wrong direction.

4. During its insertion, the thread of the screw may have rubbed the edge of the hole in the plate and sustained microscopic damage. The damage might be enough to destroy the homogeneity of the metal and to provoke electrolysis along the edge of the screw. If there is any bone reaction to the stainless steel, it is almost always found at the tip of the screw or on the edge of the groove. In the latter site, the sharp end of the screw driver

often skids and damages the metal. In such cases a local destruction of the head of the screw is found, covered by a cap of new bone. Cultures made from this region remain negative. This observation shows also why the metal should be polished, should be without scratch, and should be handled with smooth instruments and without force.

Insufficient Fixation of Plate: A plate should never be fixed to a bone with only two or three screws. Motion in the region of the fracture would result and there would be danger of delayed union or of non-union. This result of insufficient fixation of the plate has been observed many times. If only four screws are used, two of them should be inserted as nearly as possible to the line of fracture, especially if cross fixation cannot be employed; the other two should be at the very end of the plate.

Deficient Contact Between Plate and Bone: The contact between the plate and the bone surface may be deficient; in this event, there will be an empty space between the plate and the bone. This space is filled at first with fluid and blood, and later with new bone; it will delay the formation of callus in the line of fracture. When necessary, the transverse and longitudinal curves of the plate should be computed mathematically, so that the plate can be adapted perfectly to the bone. Furthermore—and this is especially important in cases of fracture with several fragments—during the insertion of the screws, the entire length of the plate must be maintained firmly against the bone. This can be accomplished only by the use of several bone clamps,—sometimes three or four. The author has devised a handy, simple, light clamp which can be used with one hand.[16] The clamps must be handled without force, so that, when they are removed, there will be no abnormal pressure on the screws. If the fracture is composed of several fragments, only the use of several bone clamps will permit a perfect reduction and thus fulfill the conditions for an optimum callus.

Short Plate: To answer the mechanical requirements, the length of the plate for the tibia should be at least equal to three times its width and, for other bones, four or five times their width. Otherwise, the pull of the muscle will exert abnormal strain on the screws of at least one fragment. This is true in cases of fresh fractures. On the other hand, if the bone is demineralized, the plate should be as long as necessary, and in certain cases should equal the whole length of the diaphysis. The quantity of metal matters little. The number of screws inserted should vary according to the degree of demineralization of the fragments and the length of the fragments, if the fracture is near the epiphysis.

Comment: The Küntscher method, which has recently been widely used in Europe, consists in inserting a wide pin through one end of the bone, along the whole length of the diaphysis.[4] Garcia Portela, in his review of 470 cases, proved that, contrary to the experiments on animals, the callus forms quickly, is only moderate in amount, and includes a periosteal and an endosteal reaction.

If an orthopaedic surgeon is confident of his technique, he should refrain from applying a plaster-of-Paris cast after open fixation, since this is detrimental to the function of muscles and joints. This function is an important factor in keeping a constant active local circulation of blood, which is one of the determining elements in securing a prompt and optimum callus.

THE USE OF BONE-GRAFTING IN OPEN FIXATION

In general, bone-grafting in open operations is only of help in securing callus in old fractures in which there is little or no response,—in other words, in which there is more or less "inertia" of the bone. In certain cases, bone-grafting may be compared with skin-grafting because it "fills the gaps" and assures bony contact in cases of bone defect; but its main value lies in its source of minerals and its improvement of vascularization. It may incidentally help fixation, but *only exceptionally should it be used as a means of fixation.* In other words, in open fixation with bone-grafting, even with massive grafts, metal fixa-

tion should be used as well, so that, except in unusual cases, one should not have to rely on plaster fixation, which is harmful for the production of callus.

Cortical Bone Grafts

Cortical bone grafts may be used as intramedullary grafts, extramedullary grafts, or grafts between fragments.

Intramedullary Grafts: Many surgeons believe that the insertion of massive grafts of cortical bone in the medullary cavity is harmful, because they destroy bone marrow and interfere with the blood supply. After extensive use of this type of graft, however, the author believes that it hastens the formation of callus and even provokes the formation of large, sometimes enormous, callus. The enormous callus which forms is one of the reasons why this type of graft should be discarded as a method of treatment of fresh fractures. The author employs intramedullary grafting of massive cortical bone as a routine procedure in two circumstances:

1. It is used in cases of non-union of long duration, accompanied by extensive demineralization. The graft, which is usually taken from the crest of the tibia, should vary in length according to the degree of demineralization. This type of graft offers three advantages in these cases: First, it increases the solidity of the plate fixation; the screws inserted through the two demineralized cortices find a strong support in the solid graft (a tap must be used). Second, it prevents too much shortening by keeping the ends of the bone slightly separated and also it prevents the formation of fibrous tissue between the fragments. (Chips of cancellous bone should be added in this area.) A third advantage is that it supplies the demineralized bone with a large source of mineral salts. The callus obtained when an intramedullary graft is used in cases of non-union is usually slow in forming, but it is solid and never excessive in amount if there is no motion in the screws and plate. The plate should be as long as the diaphysis, and the screws should be inserted obliquely to one another. A new type of plate was therefore devised by the author.[16]

2. The intramedullary graft is also used in cases of malunited fractures with dense bone tissue, or in cases of shortening of a bone after resection of a fragment. In these cases the callus is sometimes slow to form, and the newly cut ends of bone do not fit perfectly. These two reasons, together with the ones just mentioned, justify the insertion in the medulla, at the line of fracture, of a short bone peg. Without doubt, this procedure activates the formation of callus. A longer bone graft would provoke too much reaction.

Extramedullary Grafts: The graft may be an inlay or an onlay graft. Both methods of grafting usually thicken the bone considerably, and may give rise to massive bone callus. Nevertheless, the extramedullary graft has to be used in certain cases, especially when the medullary cavity is small, as in the bones of the forearm or the clavicle. The freshening of extensive portions of the bone surface is one of the causes of the extensive bone reaction. This may sometimes impair function, as in old fractures of the forearm. A great risk is involved in using such a graft or in relying upon it for fixation, even with the use of a plaster cast. Proper plating must be added to it and, if the technique is good and the plate is long enough, the use of a plaster cast can be avoided.

Grafts Between the Fragments: If the formation of a large callus is to be avoided, as for instance, in cases of defects of thin long bones like those of the forearm or the clavicle, a massive cortical bone graft of the same size as the bone can be inserted between the freshened bone fragments. Two essential requirements are imposed, however: The ends of the bone and those of the graft must be in absolute coaptation, and the plate must extend as far as possible.

Cancellous Bone

Cancellous bone is the most efficient bone for producing callus. There are two main indications for its use: (1) It may be used in cases of old fracture. Because of the inertia

of the bone in these cases, it is good always to place around the ends of bone a ring of chips of cancellous bone, taken from the same bone, from the tibia, or, better still, from the crest of the ilium. The callus formed will not necessarily be voluminous. (2) Use of cancellous bone is also indicated in certain cases of fresh fracture. A defect in bones due to the absence of a fragment, especially at the site of fracture, will always cause callus to form slowly and may be a serious risk of non-union. It is of primary importance that such a defect always be filled with chips.

Powdered Bone

Powdered bone can be produced by scratching, cutting, curetting, or drilling holes. It always promotes easy, fast, and abundant formation of bone. Its use should be avoided in fresh fractures, which should always be handled with smooth instruments. It will help greatly in cases of old fracture. In those cases, it is advisable to use a sharp, slightly curved periosteal elevator to separate the periosteum from the cortex, to scrape the cut surface of the bone with a sharp curette, to drill small holes at the ends of the fragments, and even to roughen the inside of the medullary cavity with a large drill.[9]

The author has had no experience with the influence of heterogeneous bone grafts and cadaver transplants on callus formation, and his experience with beef bone is too limited to be mentioned.

THE ROLE OF INFECTION

Infection *per se* is the dreaded enemy of the orthopaedic surgeon; yet its influence on the formation of callus cannot be overlooked. It is known that extensive acute infection will bring about necrosis and destruction of bone, and, conversely, that a mild staphylococcic infection is apt to produce extensive formation of bone, which in certain cases may reach gigantic proportions. The latter effect is probably due to a marked local activation of the circulation of blood.

In an effort to determine whether staphylococcic infection could be used to stimulate formation of bone, especially in those well-known cases in which the bone "will not react", a series of experiments on animals was started in 1926. These experiments proved definitely that the injection of cultures of attenuated staphylococci into the area of fracture greatly stimulates the formation of the bone.

THE NATURE OF THE METAL

If the callus is to be of an optimum type—that is, if it is to form quickly, become located exclusively between the ends of the bone, and not surround the material of fixation—attention should be paid to the nature of the metal. All surgeons agree that the use of an inert metal, such as stainless steel, is preferable; but too much emphasis should not be placed on this fact. In order to prevent unnecessary and abnormal reaction of bone, the most essential feature of the metal is that it be homogeneous. In other words, it should be, throughout all its mass, composed of similar crystals, without impurities, and deposited in regular layers. This is a question of manufacture. The metal should be polished perfectly, never hammered or filed, and should be handled with care, especially during the insertion of screws.

Several years ago the author used ordinary non-stainless steel, and has seen hundreds of cases in which Lambotte used it without any abnormal bone reaction whatsoever.

The effects of electrolysis on bone reaction remain mysterious. By mistake, the author used an aluminum plate and steel screws in an open fixation of the humerus. Healing took place in the normal way.[5,7,14]

Much more interesting is the effect of resorbable materials on bone.[11] In a previous study of the use of magnesium alloy on animals and in men as well (thirty-five cases), a series of factors were noted: The metal entered into solution as soon as it was inserted

into the tissues. It always provoked a minimum reaction in bone. This reaction was characterized by bone formation, the amount of which was identical with the amount of resorption of the metal. The reaction of bone was constant. If the metal crossed a joint it left the joint surfaces undisturbed after its resorption. Unfortunately, the metal gave rise to the formation of considerable quantities of gas, which had to be evacuated at intervals.

A similar alloy containing more aluminum, which would prevent its being resorbed so quickly, might provide a useful means of provoking bone reaction whenever and wherever it is wanted.

OTHER FACTORS INFLUENCING CALLUS FORMATION

The other factors which I wish to mention all concern the speeding up of bone formation; they are only worthy of consideration if the two basic factors, reduction and fixation, have been carried out perfectly. Most of them deal with the increase of the blood supply.

Early Function

Early function is a basic factor which is only practical if no plaster has been applied. It can be carried out soon (fifteen days after reduction) in the upper extremities. It is the same for the lower extremities, but here the real function consists in weight-bearing, and the time such function should start varies according to the roentgenographic findings.

Sympathectomy or Ganglionectomy

Sympathectomy or ganglionectomy is useful only if block anaesthesia with procaine hydrochloride indicates definite improvement. Its value is temporary and not constant.

Massage

Massage may be harmful and may provoke marked reaction of the bone, as well as of the soft tissues. If it is applied gently, it may help in relieving muscle spasm.

Tapping

Tapping the site of the fracture or the extremities of the fractured limb will stimulate circulation of blood and hasten the formation of callus. Its effect is negligible, however.

Short-Wave Rays

These may stimulate the circulation if used in small amounts, but the danger of provoking resorption of bone outweighs their value.

Calcium

The oral administration of calcium, alone or in the diet, is inefficient. Calcium, injected intravenously or into the fracture area, does not seem to be popular among orthopaedic surgeons. Neither does the injection of the serum of patients with fractures.

Other Drugs

Parathormone and vitamin D have been advocated. The author has had no experience with them.

Bogomolets, in 1943, suggested the use of an "antireticular cytotoxic serum", produced by inoculating horses with cells of the spleen and bone marrow taken from fresh human cadavera. He claimed that in small doses the serum has a valuable effect on the speed of bone formation. The author has had no experience with it.

CONCLUSIONS

In the treatment of fractures, surgeons are striving for the optimum type of callus exactly as they aim at obtaining a perfect skin scar.

The characteristics of an optimum callus are: (1) rapid formation; (2) its quality

(solid homogeneous bone); and (3) its quantity, which should be neither large enough to interfere with function (a large callus corresponds to a keloid) nor too small.

Surgeons have at their disposal most of the means of reaching their aim. The most important ones depend upon themselves, their principles, their methods, and their technique,—the "timing", the perfection of reduction and immobilization, the discriminating use of bone grafts, and so forth. In spite of attention to all these factors in particular cases of old fractures, surgeons will be confronted with a lack of response on the part of Nature; the bones "won't heal". (This should be the object of more research; and the author suggests the study of vaccines and of resorbable alloy.) All the means of effectively increasing the local supply of blood will be of help.

REFERENCES

1. Bogomolets, A. A.: Anti-Reticular Cytotoxic Serum as a Means of Pathogenetic Therapy. Am. Review Soviet Med., **1**: 101–112, 1943.
2. Garcia Portela, M.: El enclavamiento medular de Küntscher (470 casos). Rev. Clín. Españ., **15**: 1–14, 1944.
3. Lambotte, A., et Verbrugge, J.: Note à propos de la réaction du tissu osseux vis-à-vis du matériel de prosthèse métallique. Bull. et Mém. Soc. Nat. de Chir., **61**: 1300–1311, 1935.
4. Lopez Areal, F.: El tratamiento de las fracturas de los huesos largos por el *Marknagelung*. Rev. Clín. Españ., **11**: 353–361, 1943.
5. Massa, J.: L'ostéosynthèse métallique chez l'enfant; étude comparative des fractures non opérées. Bull. Soc. Belge d'Orthop., **11**: 176–192, 1939.
6. Murray, C. R.: Primary Operative Fixation in Fractures of the Long Bones in Adults. Am. J. Surg., **51**: 739–747, 1941.
7. Rombouts, R.: L'ostéosynthèse métallique chez l'enfant; étude casuistique et statistique. Bull. Soc. Belge d'Orthop., **11**: 160–174, 1939.
8. Verbrugge, J.: De la fixation complémentaire du péroné dans le traitement opératoire des fractures des deux os de la jambe. (Congrès français de Chirurgie, Paris, 1931.) Rev. Tech. Chir., **24**: 207–209, 1932.
9. Verbrugge, J.: A propos de l'instrumentation en chirurgie des fractures. Une nouvelle boîte de matériel. Bruxelles-Médical, **13**: 680–687, 1933.
10. Verbrugge, J.: Contribution à l'étude du traitement chirurgical des fractures récentes et anciennes de la clavicule. J. de Chir. et Ann. Soc. Belge de Chir., **33–31**: 537–543, 1934.
11. Verbrugge, J.: L'utilisation du magnésium dans le traitement chirurgical des fractures. Mém. Acad. de Chir., **63**: 813–823, 1937.
12. Verbrugge, J.: Fracture double esquilleuse, ancienne, non consolidée, avec grand déplacement, des os des deux jambes. Intervention des deux côtés en un temps. Guérison intégrale. J. de Chir. et Ann. Soc. Belge de Chir., **36–34**: 600–604, 1937.
13. Verbrugge, J.: Le traitement chirurgical des fractures ouvertes de la diaphyse tibiale. J. de Chir. et Ann. Soc. Belge de Chir., **38–36**: 68–75, 1939.
14. Verbrugge, J.: L'ostéosynthèse métallique chez l'enfant; aperçu général; déductions; conclusions. Bull. Soc. Belge d'Orthop., **11**: 126–159, 1939.
15. Verbrugge, J.: Réflexions au sujet de douze cas de pseudarthrose opérée. J. de Chir. et Ann. Soc. Belge de Chir., **39–37**: 20–28, 1940.
16. Verbrugge, J.: An Improved Bone Clamp and a Plate for Internal Fixation of Fractures. J. Bone and Joint Surg., **28**: 174–175, Jan. 1946.
17. Verbrugge, J., et De Rom, E.: Le traitement des pseudarthroses. Bruxelles-Médical, **13**: 1060–1061, 1933.

FUSION OF VERTEBRAE FOLLOWING RESECTION OF THE INTERVERTEBRAL DISC

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Complete removal of the intervertebral disc has been advocated for disc protrusion as well as for the treatment of spondylolisthesis. Some surgeons have also advised, in addition to removal of the disc, the insertion of a graft from the spinous process. It has been claimed that, by the removal of the disc, the vertebrae become fused and no movement is demonstrable three months later by maximum pressure on the spinous processes. It is further claimed that, when the broad surfaces of the bodies of the vertebrae unite, the fusion is just as perfect as by the most successful spinal graft. This union may be only fibrous at first, but it is considered sufficient to prevent any motion between the bodies of the vertebrae. It is assumed that eventually firm osseous union takes place between the bodies, but no definite proof has been presented to substantiate this postulate.

Opportunity for direct study of vertebral bodies after removal of the intervertebral disc is not available. Roentgenographic examination may be inconclusive, as minute changes are not discernible. It is known that bony fusion does not always take place after resection of the articular cartilage of other joints. Because of the difficulties just mentioned and because of inconclusive results as regards fusion of the bodies after removal of the intervertebral disc in human patients, studies in animals seemed warranted.

Accordingly, a series of six experiments were performed upon dogs of various ages in which the intervertebral discs were removed at operation. It is not the purpose of this study to discuss the diagnostic criteria for the various disc lesions, the causes of these lesions, or the results which may be expected after removal of the entire intervertebral disc. The main problem is to determine what change takes place between the bodies after removal of the intervertebral disc. Certain other conditions will be considered, particularly the effect upon movement between the articular facets and between the spinous processes.

In performing the operation for removal of the intervertebral disc, the transabdominal approach was utilized, because it was thought that a more thorough removal could be accomplished with a direct, clear exposure of the disc. Also, it was believed that less sacrifice of the structure of the vertebral bone would be necessary in exposing the disc posteriorly in a dog.

EXPERIMENTAL DATA

Dog D-1, Aged Four Years

Experiment 1 was begun on January 17, 1945; the duration of the experiment was 146 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. (The dog has seven lumbar vertebrae.) The anterior ligament was incised, and then the disc was resected and curetted as thoroughly as possible. The abdominal incision was closed in layers. No supporting dressing was applied after the operation.

At the end of 146 days the vertebral column was removed intact and was cleaned of its muscle. As seen from the abdominal side, the intervertebral space from which the disc had been removed was widened. There was a heaping up of osseous tissue on either side, but there did not appear to be complete bony bridging across the intervertebral gap. Roentgenograms showed the heaping up of bone, but not complete osseous bridging. On manipulation of the spine, there was found to be no movement between the vertebrae from which the disc had been removed; but free movement was possible between the bodies

FIG. 1

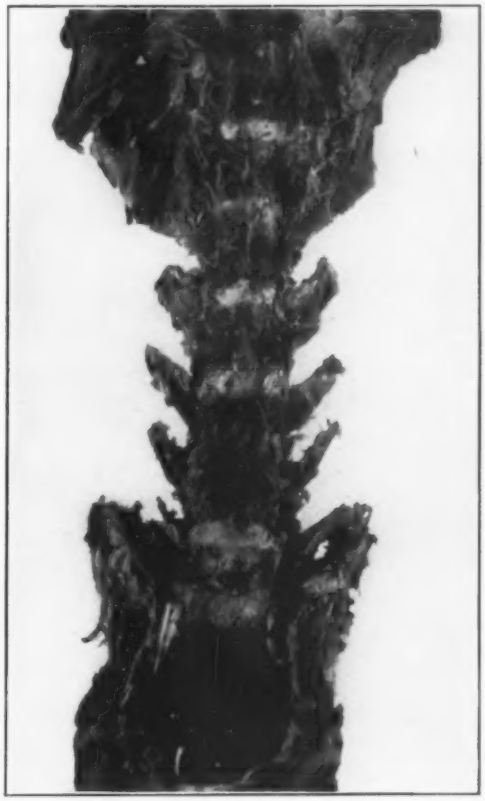

FIG. 2

Fig. 1: Dog D–1. Specimen has been split longitudinally, showing the heaping up of new bone on the abdominal side. Incomplete bony bridging in the resected disc.

Fig. 2: Dog D–2. Complete bony bridging between the vertebrae.

on either side. There was, however, very slight movement between the articular facets in the area of operation. Upon splitting the vertebrae longitudinally, a considerable heaping up of osseous tissue on the abdominal side was observed, but not complete bony bridging (Fig. 1).

There was an exudate about the nerve roots and in the extradural space. There was also some congestion of the vessels within the dura.

After the vertebrae had been split longitudinally, forcible flexion and extension produced no motion between the vertebral bodies at the site of the operation, and there was no change in length of the bodies of the operated vertebrae. Microscopic examination of a piece of tissue removed from the operative area showed osteoid tissue on the surface. Beneath the osteoid layer were bone trabeculae, with numerous marrow cells.

Dog D-2, Aged One and One-Half Years

Experiment 2 was begun on January 17, 1945; the duration was 146 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. A portion of the disc was resected, and the remainder was curetted thoroughly. The disc itself was not very wide. A small metal marker was inserted into the area in which the operation had been performed. The wound was closed in layers in the usual manner.

At the end of 146 days the gross specimen showed complete bony bridging between the two bodies from which the disc had been removed at operation (Fig. 2). There was no movement between the bodies nor between the corresponding facets. There was a slight

tendency for a dorsal protrusion of bone toward the spinal canal in the operative region. The lateral roentgenogram showed osseous tissue, projecting into the spinal canal. The vertebrae were not split for study, but were kept as a gross specimen. There was a loss of four millimeters in length of the combined measurements of the two vertebrae from which the disc had been removed at operation.

FIG. 3-A

Dog D-3. Resected disc, immediately after operation.

Dog D-3, Aged Four Months

Experiment 3 was started on January 23, 1945, and continued for 140 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. The disc was partially excised with the scalpel, and the remainder was removed as thoroughly as possible with a curette. A marker was placed in the lower vertebra (Fig. 3-A).

The findings at the end of 140 days were as follows: After the vertebral column had been dissected out, there was complete osseous bridging across the area from which the disc had been excised (Figs. 3-B and 3-C). On flexion and extension there was no movement between the bodies, the corresponding articular facets, or the spinous processes. The specimen was split longitudinally and again there was found to be a complete bony bridge between the two bodies. There was an area of degeneration in the conus medullaris at this level, which may have been due to injury at the time of the operation. The roentgenogram showed complete bony bridging between the vertebrae which had been operated upon (Fig. 3-D). There was a slight tendency for bone proliferation into the spinal column, as seen in the lateral roentgenogram (Fig. 3-E). There was also some rounding of the bodies in this region. The fused bodies measured less than they did at the time of the operation. The adjoining vertebrae showed a definite increase in length. Some loss would be expected to result from removal of the disc tissue and some from injury to the epiphyseal plate, as this was a growing animal.

Dog D-4, Aged Four Months

Experiment 4 was started on January 23, 1945; the duration of the experiment was 140 days. At operation the disc between the fourth and fifth lumbar vertebrae was exposed through a mid-line abdominal incision. The disc was partially excised and was then thoroughly curetted. A marker was placed in the body of the proximal vertebra.

Upon exposing the operated area at the end of 140 days, there was found to be complete bony bridging between the two bodies from which the disc had been removed. There was no movement between the bodies. There was no motion between the articular facets, corresponding to the operated vertebrae. The articular cartilages of the facets appeared

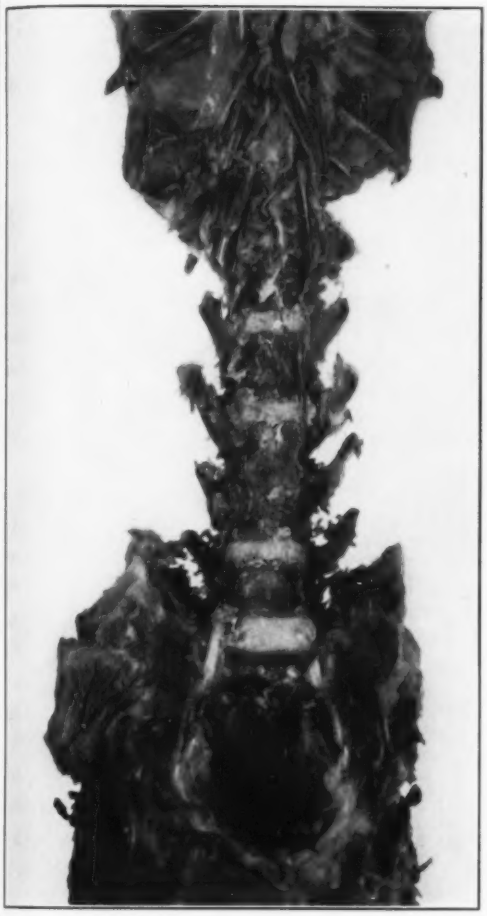

FIG. 3-B

FIG. 3-C

Show complete bony bridging in the disc,—anteroposterior view (Fig. 3-B) and lateral view (Fig. 3-C).

a little thinner than normal. There was no movement of the spinous processes of the vertebrae which had been operated upon, although those outside of this area moved very freely. Upon opening the spinal canal, an enlargement of the cord at the site of the fused disc was seen. Considerable hemorrhagic exudate was observed along the anterior border of the canal; it extended along several vertebrae. An adhesion extended from the disc to the dura. Upon opening the dura, some engorgement of the blood vessels was noted.

The roentgenograms showed the fusion between the vertebrae at the site of operation. There was a loss in length of the fused vertebrae, and some dorsal convexity of the fused bodies of the vertebrae.

Dog D-5, Aged Four Months

Experiment 5, which was begun on January 31, 1945, was continued for forty-three days. At operation, through a lateral lumbar approach, the body of the second lumbar vertebra was exposed, after the transverse process had been removed with an osteotome. The disc between the second and third lumbar vertebrae was partially resected and then curetted.

At the end of forty-three days, a loss of tissue was observed between the two vertebrae. There was some motion between the bodies, but considerably less than normal. There was no evidence of new bone. The disc had been replaced by dense fibrous tissue.

FIG. 3-D

FIG. 3-E

Fig. 3–D: Anteroposterior view, showing complete bony bridging with fusion of the bodies.
Fig. 3–E: Lateral view, showing fusion of the bodies, with a tendency for posterior projection of bone into the vertebral canal.

No changes were found in the canal or about the cord. The roentgenograms showed thinning of the disc.

On microscopic examination, there were heavy, dense trabeculae and osteoid tissue, similar to the callus seen in the healing of a fracture. Some of the osteoid tissue looked like the young cartilage tissue found in the nucleus pulposus.

Dog D-6, Full Grown

Experiment 6 was begun on January 31, 1945; the duration was 122 days. At operation, through a mid-line incision and transabdominal approach, the disc between the fourth and fifth lumbar vertebrae was exposed. The disc was incised and as much as possible was removed with the curette. A metal marker was placed in the proximal vertebra.

Upon exposing the operated disc on the abdominal surface at the end of 122 days, a mass of bone was seen on each lateral margin, connecting the two vertebrae. These masses were rounded and projected almost 0.5 centimeter. Between the two lateral sections of bone, there was some tissue of softer consistency. The dura was exposed by removing the spinous processes and the laminae. There was some hemorrhage along the anterior surface of the spinal canal. The dura was adherent to the area of the dissected disc. There were no changes within the dura.

The anteroposterior roentgenogram showed complete bony bridging on both lateral aspects of the vertebrae, with an area of diminished density between them. The lateral view showed osseous bridging on the anterior surface, with less dense tissue between the bodies of the vertebrae.

There was no increase or decrease of growth of the normal vertebrae or of the vertebrae which had been operated upon.

Microscopic examination revealed that the section from the lateral pieces of tissue was made up of an outer layer of bone, beneath which was osteoid tissue. Numerous marrow cells were in the spaces between the bone. The inner layer of tissue was composed of cartilage cells. The process was similar to that of a healing fracture in a long bone.

COMMENT

Complete bony bridging occurred between the bodies of the vertebrae of dogs after the intervertebral disc had been removed. The bone proliferation was more active in young animals.

When firm osseous union took place, the combined length of the two vertebrae which had been operated upon was less than before operation; when union was not completely osseous, there was no diminution in length. With bony union, buckling toward the spinal canal tended to occur, which might account for some loss of length. If a disc operation is performed upon a growing individual, one should take into consideration the possibility of retardation of growth, with resulting deformity of the spine.

In the removal of the disc from the abdominal side, there was evidence of injury to the dura and cord. Likewise, in the dorsal approach there is danger of injuring the large vessel on the abdominal side. Care should be taken to avoid such injuries.

After the intervertebral disc had been removed, there was no gross evidence of displacement of the articular facets.

Although none of the operations were performed by the dorsal spinal approach, it can be predicated from the results of these experiments that, in dogs, if the disc is thoroughly removed so as to expose the bone on either side, osseous union will take place between the two bodies. The method of union is similar to that observed in the healing of fracture in a long bone.

CONCLUSIONS

Complete osseous union took place in dogs between the bodies of the vertebrae, following removal of the intervertebral disc. In young animals the union was more rapid and more likely to be completely osseous.

Complete bony union between the bodies produced sufficient fixation to prevent movement between the articular facets and between the spinous processes. When union was incomplete, there was considerable fixation of bodies, but movement took place between the articular facets.

KNEE FUSION BY THE USE OF A THREE-FLANGED NAIL *

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In doing an arthrodesis of the knee for Charcot's disease in February 1943, it was found that stability could not be secured by the usual methods of fusion. The presence of degenerative changes with fragmentation necessitated such extensive resection before viable bone was exposed that the resulting joint had a gap of one and one-quarter inches, and the transplanted patella failed to stabilize the site of arthrodesis. The debrided knee surfaces were held together manually and a vitallium nail of the Smith-Petersen type was driven across the joint space after the tibial graft had been implanted. Excellent stability was achieved immediately. Recovery was accompanied by complete ankylosis (Fig. 1-C).

The same procedure has been used since that time to provide stability in cases where ankylosing operations were performed for Charcot's joints, arthritis, residual poliomyelitis, old suppurative arthritis, spastic hemiplegia of the aged with fixed flexion deformity, completely relaxed ligaments (hydrocephalus), and in those knees where the patella had previously been removed. The author has avoided it to date where tuberculosis was present; in one tuberculous knee, fused elsewhere by this method, amputation was necessary later. Secondary infection—which frequently occurs in conjunction with such lesions—spread along the nail tract, causing massive disorganization.

On the basis of clinical experience the author believes that, where indicated, this procedure is valuable; and hence it is being presented.

OPERATIVE PROCEDURE

The usual anterior horseshoe incision should be extended upward on the medial side to expose the upper portion of the medial femoral condyle (Fig. 2-A). The ligamentum patellae and the capsule are divided, and the synovial membrane is completely removed. The posterior two thirds of the patella is removed, and either discarded or used as a free graft. The cortex of the upper anterior portion of the tibial tuberosity is removed to expose cancellous bone for patellar contact. A section of the patellar ligament is removed, so that, after suture, the patella is drawn down into contact with both the tibia and the femur. Débridement of the joint, with removal of the cartilage from the femoral and tibial condyles, is done. The tibial spines and cruciate ligaments are excised. This leaves a larger surface of tibial plateau for contact with the flattened surface of the femoral condyle. The menisci are excised. In cases of Charcot's disease of the knee joints, the ends of the tibia and femur are cut away until viable bone is secured. Good apposition of the flat surfaces should be obtained, with the knee straight. At first the patella was transplanted, as in the Hibbs fusion technique. Now, flat surfaces of the femur and tibia are nailed, with no free graft interposed. The deep surface of the remainder of the patella acts as a viable graft across the joint. A vitallium nail of the Smith-Petersen type is driven from the upper surface of the medial femoral condyle downward through the condyle and through the tibial head and shaft (Figs. 2-B and 2-C). A screw has been placed obliquely through the patella into the tibia to hold the patella down and firmly apposed. Routine closure and dressing are carried out. A snug-fitting, long plaster boot is applied. After from ten days to three weeks the foot portion of the boot is removed; for the next three months only a cylinder cast is used. Occasionally the cast is removed and a long leg brace is applied. Except in cases of Charcot's joints, the patient may become ambulatory on crutches three weeks after operation.

* Read at the Orthopaedic Section of the Medical Society of the State of New York, New York City, May 1944; and at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 21, 1946.

REVIEW OF CASES

Arthrodesis of eighteen knees has been performed by this method since February 1943. In four of the cases it is less than three months since operation, and ankylosis has not yet been secured.

In two of three instances of Charcot's joint, the knees became solid. Three knees with infectious arthritis, two of which had previously had sinuses, have become ankylosed. Arthrodesis was completed successfully in five patients with osteo-arthritis; and in two patients, fusion was achieved for residual poliomyelitis with instability. One relaxed, unstable knee in a patient with severe hydrocephalus became ankylosed. Of the first fourteen cases, union was secured in all except one with a Charcot's joint and severe disintegration. This patient is now ambulatory, and weight-bearing is possible with the aid of a cane and a long leg brace.

Of the patients in whom union was secured, all support was removed and full weight-bearing was possible in from three to six months, except for one syphilitic patient with a

FIG. 1-A and FIG. 1-B FIG. 1-C

Fig. 1-A: Charcot's disease of the knee, showing massive derangement.
Fig. 1-B: Fusion has been secured by the methods described.
Fig. 1-C: Weight-bearing is possible on the ankylosed knee after operation.

Fig. 2-A

Fig. 2-B

Fig. 2-C

Fig. 2-A: Inset shows horseshoe incision, extending upward on medial surface of knee joint to expose medial femoral condyle. There is good apposition of bone surfaces. Implantation of patellar graft is shown. Insertion of nail in medial femoral condyle is indicated.

Fig. 2-B: Knee is flexed to show position of the nail as it starts to traverse the joint space. Note that the upper surface of the tibial tuberosity is cut clean across; the spines of the tibia and the cruciate ligaments have been removed, giving a much wider area for ossification between the femur and tibia.

Fig. 2-C: Showing the position of the nail, fully driven into the femoral condyle and tibial head, traversing and stabilizing the joint space.

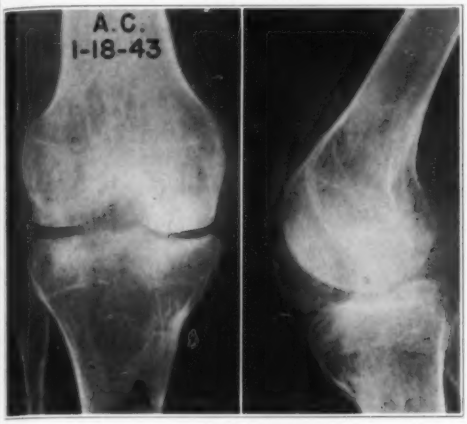

FIG. 3-A

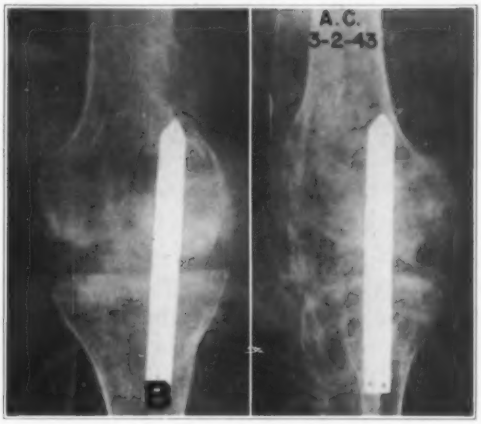

FIG. 3-B

Fig. 3-A: Knee of patient with poliomyelitis. Massive relaxation and a great deal of bone atrophy were present.

Fig. 3-B: Fusion achieved by method described, with separation of bone elements due to relaxation.

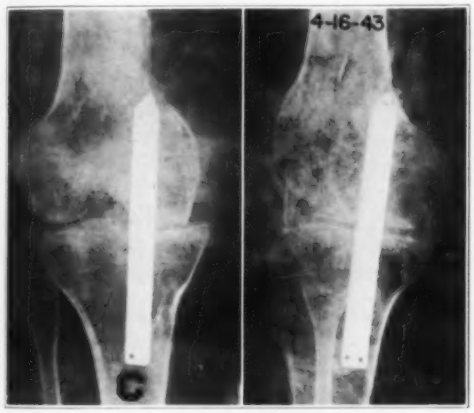

FIG. 3-C

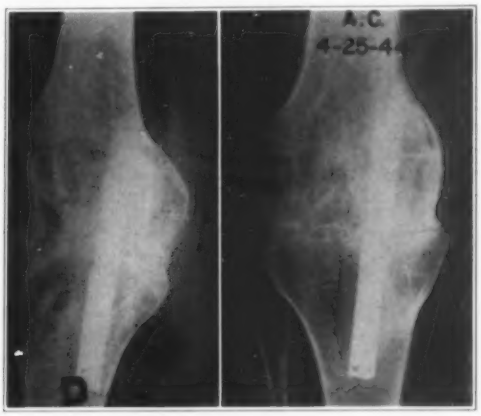

FIG. 3-D

Fig. 3-C: Coaptation was secured by impaction through manual percussion on the heel.

Fig. 3-D: Arthrodesis has been secured. Note action of patella, crossing the joint as a free graft. Here, and in Fig. 1-B, a headless vitallium nail was used; in this instance the nail was inserted with the square end first. A nail with a head is now employed.

Charcot's joint. This patient had had an attempted knee fusion previously, which had failed. Union occurred with reoperation by the method described, and in this case a year elapsed before full weight-bearing could be undertaken. Hospitalization was necessary for from three to five weeks, except in the cases of Charcot's disease and in the patients who had poliomyelitis. The latter patients remained in the hospital for a longer period, because of other operative procedures. One other patient, who required hospitalization for two and a half months, had an unsuspected sensitivity to iodine, benzoin, adhesive tape, penicillin, and numerous other drugs. Her allergic manifestations were so severe as to cause her to be extremely uncomfortable for almost a month after operation.

No other postoperative complications were encountered, and there were no deaths. One patient suffered a gunshot wound of the femur four months after operation, without disturbing the fusion. All wounds healed primarily, except in one recent case; this patient has been found two months after operation, although afebrile, to have several sinuses through the incision line.

The nail has been removed in one case only. In this instance, the patient complained

of tenderness over the base of the nail. She was readmitted to the hospital, after complete ankylosis had occurred, and the nail was removed easily through a stab incision. Two of the patients had arthritic lesions in the other knee of less extent than those in the knee which was arthrodesed. Both of these patients have felt that their "good" knees were improved after the weight-bearing facility provided by the ankylosed knee. Hip spicas or braces were not used; long leg splints were sufficient. A few thin headless nails were used at first, but ordinary four-inch hip nails of the Smith-Petersen type have been found satisfactory.

This method has not been used where (1) tuberculosis was present, (2) where an open epiphyseal line would have to be crossed by the nail, or (3) where osteomyelitis had been present or suppurative arthritis was still active. In these instances, a Hibbs fusion or simple resection has been done. Where growth is almost complete, crossing the epiphyseal plates with a nail is permissible.

This method of fusion offers the following advantages:

1. A long plaster boot only is necessary. The short, fat woman who needs knee fusion therefore presents a simple problem. By this technique the plaster hip spica, previously used, can be avoided.

2. The period of hospital care is shortened.

3. The devitalized free graft, which requires more time for complete ossification, may be dispensed with. In several of these cases the knees have become solid and fully weight-bearing within three months.

4. Not only is stability gained immediately; but the nail permits continued apposition of the bone surfaces, in case absorption or separation takes place before union has occurred. By early repeated manual impaction on the heel and, later, by partial weight-bearing with crutches, the tibia may be made to slide on the nail and to come into contact with the femur; but it cannot become displaced laterally, and union will occur (Figs. 3-A, 3-B, 3-C and 3-D). The bone surfaces of relaxed knees (such as are seen in poliomyelitis) are also more easily kept in contact by this method.

DISCUSSION

Dr. Allen F. Voshell, Baltimore, Maryland: Dr. Bosworth has suggested a new and rather simple method of more closely apposing the surgically prepared surfaces of the femur and tibia, when fusing knee joints in adults suffering from Charcot's disease and its joint disintegration. Any procedure which will hold the two freshened bone surfaces close together until new bone tissue can bridge the space is advantageous. An obliquely placed nail; a loop of strong wire; staples, such as Blount uses in epiphysiolysis; or transfixed pins above and below are some of the satisfactory methods of stabilization. It would seem that a method allowing progressive "snugging up" of the surfaces might be better; but I was interested to note that, in the slides shown by Dr. Bosworth, there was no spreading apart of the bone ends and no degeneration about the pins or sliding of the pins. This seems to me to be the gauge of the efficiency of the method, provided fusion does occur.

The position of fixation shown is with the leg in full extension. This brings up the question of the better utility of some flexion; flexion allows greater comfort when sitting and still doesn't detract from stability.

By tradition, I would be opposed to the use of this procedure in tuberculosis, due to the effects upon the epiphyses and the trauma to good bone tissue nearby, with the possibility of spreading the disease.

I shall be interested to hear further from Dr. Bosworth, after he has had more experience.

Dr. Edwin W. Ryerson, Chicago, Illinois: The use of the three-flanged nail in arthrodesis of the knee joint is an excellent procedure. It will prevent rotation and will afford good fixation.

In adults, I think the knee should be fused in about 15 degrees of flexion, as this position is more generally useful than full extension. Children's knees, however, should be perfectly straight, because even a few degrees of flexion will inevitably become exaggerated to a full 90 degrees in the course of time.

TREATMENT OF CONGENITAL DISLOCATION OF THE HIP *

BY EDWARD L. COMPERE, M.D., AND WILLIAM J. SCHNUTE, M.D., CHICAGO, ILLINOIS

From the Department of Bone and Joint Surgery, Northwestern University Medical School, and The Children's Memorial Hospital, Chicago

The most common cause of failure in the treatment of congenital dislocation of the hip, in children four years of age or younger, has been the discontinuance of immobilization before an adequate acetabulum has been formed by the pressure and function of a reduced and articulating femoral head. No good criteria have been described for determining when to discontinue cast or splint fixation after reduction of the dislocated hip. Some surgeons have recommended that the hip should be kept immobilized for five months; others recommend seven, nine, or twelve months, or longer. Most orthopaedic surgeons discontinue immobilization when the hip joint appears to be stable.

Many patients, after reduction of a congenitally dislocated hip and immobilization for varying periods of time, still have markedly inadequate acetabula, although the femoral heads may not become redislocated. An inadequate acetabulum will result in disability, and redislocation may occur later in life.

Poor end results in the treatment of congenital dislocation of the head of the femur will be much less common, if the reduced hip is held securely in the acetabulum until a thoroughly adequate hip joint can be demonstrated roentgenographically. To be acceptable, the hip must be relatively normal from the standpoint of depth and slope of the superior portion of the acetabulum, and the remodeling of the femoral head and acetabulum must be such that they fit accurately and articulate smoothly.

Surgeons are aware of the harmful effects of long periods of inactivity which may result from continuous immobilization in plaster, and this has influenced their decisions with respect to the time when all splinting should be discontinued. For several years the authors have used a modified Denis Browne splint as a part of the treatment of congenital dislocation of the hip. Rotation of the limb is under complete control, and a long bar between the two foot plates maintains wide abduction. With this as a convalescent splint, continuous pressure of the head of the femur in the acetabulum has been maintained, without rigid immobilization.

The deepening and molding of the hip joint after prolonged functional splinting conform to the law of functional adaptation described by Wolff, which states that every change in the form of a bone or of its function is followed by certain definite changes in its internal architecture and equally definite secondary alterations in its external form.

The orthodontists are able to reshape the bones of the jaw completely by means of very mild pressure applied to the teeth for prolonged periods. A similar principle holds with respect to the deepening and molding of the acetabulum and reshaping of the head of the femur. In either instance, however, a period of many months or even of years may be necessary in order to obtain a completely satisfactory end result.

Every experienced orthopaedic surgeon has observed the development of a secondary acetabulum in the ilium, above the unused acetabulum, in cases of old unreduced congenital dislocation. The forces which produced the secondary acetabulum are multiplied by use of the spreader splint to remodel the true acetabulum. Hourglass constrictions of the capsule of the hip joint will be dilated, or fat and fibrous tissue in the acetabulum will be compressed until absorbed, if this same molding pressure is maintained for a long enough time after the dislocation has been reduced.

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

When the abduction splint is used, atrophy of disuse—either of muscles or of bones—is minimum, because the extremity may be exercised while the contact and pressure of the femoral head are maintained in the acetabulum. The movement of the hip in the acetabulum helps to reshape the articulation and to make a more normally functioning joint than is possible from the static pressure obtained in a "frog-leg" cast or a plaster hip spica (Fig. 1). The abduction splint permits flexion and extension in the hip joints. Patients may sit up and some of them have even managed to walk. When stability of the hip permits, the splint may be removed daily for bathing and, as the acetabulum deepens, for longer periods of activity. Perhaps its greatest usefulness is as a convalescent splint which may be worn at night for two or more years, while unrestricted walking and all activity are permitted throughout each day.

FIG. 1

Spreader cast which is worn until the hip appears to be sufficiently stable to make it safe for the use of the removable convalescent splint.

Attempts have been made to subdivide congenital dislocations of the hip into several groups, depending upon the period of development in which the dislocation originated. However, many embryologists, anatomists, and orthopaedic surgeons are unwilling to accept such theoretical divisions as foetal, natal, or postnatal dislocations. Although there are various degrees of acetabular dysplasia, with varying positions of the head of the femur in its relationship to the acetabulum, most cases are hereditary in origin. As Stewart has aptly stated: "The pathology of congenital deformities is sown in heredity, develops in embryo, and fruits under the trade winds of use". The differentiation of the hip joint is completed in the ninth week of foetal life, and the adequacy of the articulation has been determined before that.

Detailed anatomical dissections of the hip joints and surrounding tissues of a girl aged seven years, who died three months after manipulative reduction of congenitally dislocated hips, were made by Allison in 1905. From these dissections and from observations made during clinical studies, Allison concluded that the basis of the pathology was as follows:

1. A poorly developed acetabular cavity.
2. An underdeveloped and irregularly shaped femoral head.
3. An abnormal direction of the neck of the femur.
4. Shortening of the adductor group of muscles. (These muscles were found to have been injured by the forced manipulative reduction, both in the muscle elements and in the nerve supply to the muscles.)
5. Shortening of the posterior muscles, the fascia lata, the iliotibial band, the iliofemoral band, and of all pelvitrochanteric muscles.

A completely satisfactory result of treatment of a congenitally dislocated hip should include correction of each of these abnormal conditions.

Twenty-three years later, Allison reported a clinical study of marked pathological changes which developed over a period of years in congenitally dislocated hip joints, although the dislocations had been reduced during infancy or early childhood and the reduc-

tions had been maintained. He decided that the degenerative arthritic changes were caused by the persistently inadequate depth and abnormal shape of the acetabula. The patients had been treated by cast immobilization long enough to prevent redislocation, but not sufficiently long to permit the acetabulum and the head of the femur to become accurately adapted to each other. Allison thought also that much permanent deformity resulted from the use of force in the reduction of congenital dislocations.

Ghormley has reported hypertrophic arthritis of the hip, which occurred in adult life, in a series of patients whose hip joints were congenitally inadequate. The arthritis occurred in these subluxated hips regardless of whether they were congenitally deficient, or remained inadequate after the reduction of congenital dislocations because treatment had been discontinued too early.

Neither Allison nor Ghormley supplied the answer to the problem which they described. Only rigid fixation was being used in the earlier years. The objections of Allison to prolonging rigid fixation beyond the time when the reduction could be maintained without it are now obviated by a splint, which permits motion in the hip joints while still maintaining position.

The purpose of this presentation is to re-emphasize the value of movement and function, as well as of prolonged positional splinting, in the development of a completely satisfactory hip joint after reduction of a congenital dislocation. The plan of treatment described here has been used by the authors for three years. Sixteen patients have been so treated. Of these, two had bilateral dislocations. The youngest patient was five months old at the time of beginning treatment, and the oldest was just over three years of age. The use of a removable abduction night splint, which permits motion in the hip joint, was described by one of the authors.[4]

No statistical analysis or end-result study can be made until these patients are several years older. The authors' observations, however, support the conclusions of Ponseti. He described a similar method of management of congenital dislocation of the hip, and stated that a satisfactory development of the hip joint could be obtained by prolonged abduction splinting without immobilization.

CASE REPORTS

The following cases, observed by the authors, illustrate the application of this method of treatment:

CASE 1. S.B., a girl, aged one year, had congenital dislocation of the right hip. In July 1943 the dislocation was reduced by gentle manipulation, under general anaesthesia. A "frog-leg" cast was applied to maintain 90 degrees of abduction. Three months later this position was changed to 45 degrees of abduction and slight internal rotation of the right lower extremity, maintained by a single hip spica cast.

In January 1944 the cast immobilization was discontinued, and a Denis Browne splint with a long spreader bar was applied. In February the patient was trying to stand while wearing the splint and fell, suffering a greenstick fracture of the right femur. A hip spica cast was reapplied. In March the cast was removed, and the right hip was found to be subluxated. The spreader splint was reapplied, with immediate reduction of the dislocation.

Approximately one year from the date of beginning treatment the hip was completely stable; the spreader splint was then removed for one hour each day. The splint-free time was increased an hour every week. By October 1944 the patient was given complete freedom of activity throughout each day, but splints were worn at night. In December the patient walked or ran without any limp. The roentgenograms, however, showed the hip joint to be shallow, with a sloping acetabular roof. The night splints were continued.

In December 1945, two and one-half years after the initial reduction, the right hip was normal from the standpoint of function, and completely satisfactory roentgenographically. Torsion of the femur had been corrected. However, since the night splinting did not interfere in the least with the comfort or rest of this patient, it was planned to continue it for at least six more months.

CASE 2. A.W., a girl, aged one year, had congenital dislocation of the right hip. In February 1944 manipulative reduction was carried out, and a cast was applied to maintain the lower extremities in

FIG. 2-A

FIG. 2-B

Case 4 (L.F.)

Fig. 2-A: Arthrogryposis with congenital dislocation of hips, bilateral congenital dislocation of knee, and bilateral talipes equinovarus.

Fig. 2-B: Method used for reducing, without undue force, hips which were held almost rigid by surrounding fibrous tissue. Note pressure pads applied against trochanters.

FIG. 2-C

FIG. 2-D

Fig. 2-C: *Position 2*: Wide abduction with only moderate internal rotation for maintaining reduction of both hips.

Fig. 2-D: Convalescent splint which may be removed for bathing; later it will be worn only at night. Splint will not be discontinued for two or three years, or until roentgenograms show a thoroughly adequate acetabulum and smoothly articulating femoral head for each hip.

90 degrees of abduction. In August a Denis Browne splint with a spreader bar was applied. Three months later, reduction was secure. Splints were discontinued during the day, but applied at bedtime.

By October 1945 function was completely normal. Roentgenograms revealed a well-developed acetabulum, although the capital femoral epiphysis showed some retardation of development.

CASE 3. R.H., a boy, aged eight months, had dislocation of the right hip. Preliminary stretching

of unusually short and tight adductor muscles was instituted for ten weeks by means of bilateral toe-to-groin casts, maintained in progressively increased abduction by a long spreader bar.

In December 1944 the dislocation was reduced successfully by manipulation. A "frog-leg" cast was applied. Three months later, this was replaced by an abduction hip spica.

FIG. 2-E

Roentgenogram of congenital dislocation in connection with arthrogryposis, showing the high displacement after treatment was started.

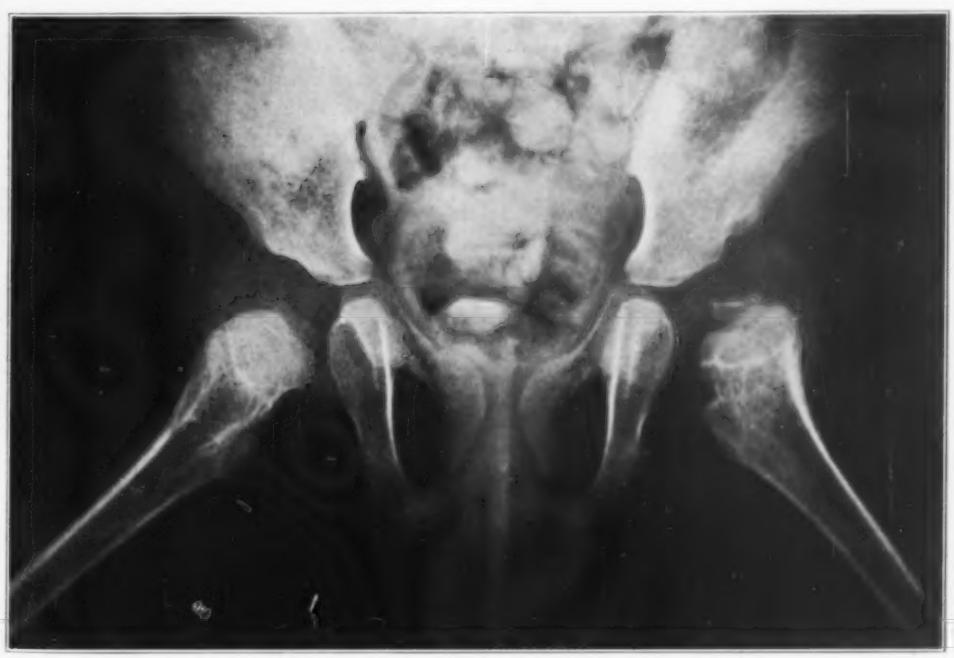

FIG. 2-F

Twelve months after reduction; the position is being maintained in long spreader convalescent splints. Note slight flattening of ossification center of femoral epiphyses. Acetabulum, however, is beginning to deepen. Splints will be continued until the articulation is completely satisfactory.

In September 1945, a Denis Browne splint with an abduction bar was applied. On examination in December 1945, the reduction had been maintained and the acetabulum was developing satisfactorily. It was decided to begin leaving the splint off during part of each day. A night splint was to be continued for at least one more year.

CASE 4. This patient had arthrogryposis, with bilateral dislocation of hips and knees and talipes equinovarus deformities. The dislocations were very difficult to reduce, since motion of all joints of the lower extremities was restricted by extensive fibrosis. A preliminary period of abduction and traction made it possible to accomplish the reduction without undue force. Spreader splints now maintain reduction of the dislocation in the hips and correction of the club-foot deformities, and at the same time permit exercise of hips, knees, and ankle joints (Figs. 2-A to 2-F).

FIG. 3

Abduction casts, which are extended onto the thigh to relieve some of the strain on the knee. This type of fixation replaces the abduction spica cast of the body and lower extremities.

Many different types of splint have been used in attempts to obtain reduction without forceful manipulation and to maintain reduction without the prolonged use of plaster casts, which immobilize both the hip joint and one or both lower extremities. Putti devised and used an abduction splint, consisting of two boards that were padded and hinged together at one end. He was successful in obtaining reduction of dislocations of the hips in children, whom he treated during the first few months of life by gradually increasing abduction of the lower extremities. After the reduction had been maintained for two or three months, the splint was replaced by a wedge-shaped cushion

FIG. 4-A

FIG. 4-B

Removable convalescent splint applied about six months after the initial reduction. May be removed for bathing and later left off for increasing periods each day, provided the reduction of the hips remains stable, as shown by examination and roentgenograms. After about two months, it is left off all day, but should be continued as a night splint for an indefinite period of time,—probably not less than two years.

covered with waterproof cloth. This program of treatment was continued for from eight to twelve months.

Ridlon, who was also a keen observer, recognized the primary defect of malformation of the acetabulum, and the secondary fact of maldevelopment of both the acetabulum and the head of the femur, because of the lack of functional stimulus in the dislocated hip. Coonse described a modification and improvement of the Putti splint and later, together with Stewart, reported a series of cases which were treated successfully by this method. Jaeger used a wide abduction splint and added a pressure pad over the trochanter to aid in deepening the acetabulum. Freiberg incorporated turnbuckles in plaster casts which had been applied bilaterally from the mid-thigh down to and including the foot. By this

means he was able to increase abduction until the heads of the femora were reduced into the acetabula.

The importance of movement and function in the growth of the infant and of the development of the muscles and bones of the limbs was recognized by Galland. He advocated the use of bilateral spica casts which extended only to the knees; motion of the ankles and knee joints was permitted, while the thighs were held in a position of complete abduction.

Schwartz recently reported the successful treatment of a case of bilateral congenital

FIG. 5-A

Roentgenogram of bilateral dislocation of the hips before treatment.

FIG. 5-B

Roentgenogram taken twelve months after the initial reduction. The acetabula have developed satisfactorily, and there is no evidence of damage to the heads of the femora. The spreader night splint is still worn and will be continued for at least one more year, although this patient is ambulatory and has no limp.

FIG. 6-A

FIG. 6-B

The type of chair used at Children's Memorial Hospital for children in the "frog-leg" or abduction plaster casts.

dislocation of the hip by means of a spreader cast, applied only to the lower extremities, with the knees flexed 90 degrees and with the addition of a V-shaped plaster instead of a straight crossbar. This maintained a position of 90 degrees of abduction, but still permitted the patient to sit up. Thus, Schwartz also recognized the importance of freedom of rotation of the pelvis on the fixed femoral head in the more rapid development of the acetabulum.

Although the authors were not informed of his work, Ponseti, in the clinic of Dr. Arthur Steindler, began using a removable spreader splint and plan of treatment almost identical with ours. The authors have no desire to try to establish priority with regard to any part of the principle which has been discussed. They are sufficiently enthusiastic about the advantages of this program of care to urge others to try it.

The plan of care which the authors have adopted as a routine is as follows:

Position 1: The lower extremities are maintained in the "frog-leg" cast, in 90 degrees of abduction, for two months.

Position 2: An abduction spica cast is maintained for two months (Fig. 2-C).

Position 3-A: Bilateral casts of the lower extremity, held widely apart by means of a plaster strut to maintain constant abduction and slight internal rotation, are used for two months. This type of cast has the advantage of permitting the patient to sit up and to be reasonably active. It cannot be removed by an unwise parent at the risk of redislocating the hip (Fig. 3).

Position 3-B: A Denis Browne splint with a long spreader bar is worn for two months, but removed each day for the bath (Figs. 4-A and 4-B). The hip should be stable, but will still reveal a shallow acetabulum.

Position 3-C: The spreader splint is left off for one hour, morning and afternoon, but is worn for the remaining twenty-two hours each day. Each week an additional hour of freedom from the splint is added, until it is finally left off during all of each day. The splint should be reapplied at bedtime each night, until the hip joint appears to be normal,—both

from the standpoint of function and roentgenographically. The night splint should not be discontinued until roentgenograms show an approximately normal hip joint with good depth, normal slope to the roof of the acetabulum, and a well-formed and well-rounded head of the femur. The torsion of the femur will be corrected, in most cases, without the necessity of an osteotomy (Figs. 5-A and 5-B).

Experience with this method has encouraged the authors to express the opinion that most congenital dislocations of the hip can be reduced, the reduction maintained, and a relatively normal hip joint—from the anatomical and functional standpoints—developed by means of prolonged functional splinting. Patience and perseverance on the part of the surgeon will be rewarded by reduction without trauma, and by stability of the hip without loss of function and without pain and disability from osteo-arthritis and subsequent deformity. When treatment can be started before the patient is four years of age, open reduction should not be necessary. Regardless of age of the patient or method of obtaining the reduction, the long abduction splint should be used at night for as many years as may be necessary in order to obtain a completely adequate acetabulum and smoothly articulating femoral head.

REFERENCES

1. Allison, N.: A Study of the Anatomy of Congenital Dislocation of the Hip After Manipulative Reduction. Am. J. Orthop. Surg., **3**: 157–170, Oct. 1905.
2. Allison, N.: The Adaptive Changes in the Hip in Congenital Dislocation and Their Importance in Treatment. J. Bone and Joint Surg., **10**: 687–695, Oct. 1928.
3. Browne, Denis: Talipes Equino-Varus. Lancet, **2**: 969–974, 1934.
4. Compere, E. L.: Orthopaedic Correspondence Club Letter, Jan. 1945.
5. Coonse, G. K.: A Simple Modification of Putti's Splint for the Early Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **13**: 602–605, July 1931.
6. Coonse, G. K., and Stewart, W. J.: Further Observations on the Abduction-Traction Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **16**: 303–311, Apr. 1934.
7. Freiberg, J. A.: Early Diagnosis and Treatment of Congenital Dislocation of the Hip. J. Am. Med. Assn., **102**: 89–93, 1934.
8. Galland, W. I.: Congenital Dislocation of the Hip. With Special Consideration of After-Treatment Following Closed Reduction. Surg., Gynec., and Obstet., **54**: 88–94, 1932.
9. Ghormley, R. K.: Lesions of the Hip in Childhood and Adolescence and Their Relation to Lesions of the Hip in the Adult. Rocky Mountain Med. J., **37**: 956–961, 1940.
10. Jaeger, C. H.: Congenital Dislocation of the Hip. Diagnosis and a New Method of Treatment in Infancy. Surg., Gynec., and Obstet., **50**: 757–761, 1930.
11. Ponseti, I.: Causes of Failure in the Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **26**: 775–792, Oct. 1944.
12. Putti, V.: Early Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **11**: 798–809, Oct. 1929.
13. Ridlon, J.: Congenital Dislocation of the Hip. Rhode Island Med. J., **16**: 135–138, 1933.
14. Schwartz, R. P.: V Plaster Splint for Maintaining Reduction of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **27**: 166–167, Jan. 1945.
15. Stewart, S. F.: The Physiological Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **17**: 11–17, Jan. 1935.
16. Wolff, J.: Ueber die innere Architectur der Knochen und ihre Bedeutung für die Frage vom Knochenwachsthum. Virchows Arch. f. path. Anat., **50**: 389–450, 1870.
17. Wolff, J.: Die Lehre von der functionellen Pathogenese der Deformitäten. Arch. f. klin. Chir., **53**: 831–905, 1896.

DISCUSSION

Dr. H. R. McCarroll, St. Louis, Missouri: This principle in the management of congenital dislocation of the hip has been attempted in many varied ways. It has at times been used in an attempt to accomplish the reduction itself, but for this it has never been very successful. Its use, as described by Dr. Compere, is, in my estimation, not so simple or so perfect as his paper would lead us to believe. There are five points which I wish to stress:

1. The "frog-leg" position employed as Step No. 1 is, I believe, unnecessary. The initial fixation could as well be one of internal rotation and abduction.

2. Dr. Compere apparently uses a preliminary manipulation for reduction of the hip. Changes taking place in the femoral heads of patients so treated in past years have been due to damage, resulting from the manipulation; and to a pressure necrosis, resulting from the tremendous force of the capital epiphysis against the acetabulum. This was Dr. Crego's primary reason for the institution of preliminary skeletal traction in these patients. Dr. Compere's patients, whose dislocations have been manually reduced and whose hips have been fixed in abduction for many months, can reasonably be expected to show similar changes a few years from now. Force exerted against these femoral heads is a more important factor than an inadequate acetabulum in the development of these early degenerative changes.

3. Dr. Compere states that a fold of capsule or fibrous tissue in the acetabulum will disappear if this treatment is continued long enough. He fails to mention that an occasional case is encountered in which the acetabulum is so completely filled with fibrous tissue that reduction is utterly impossible until the tissue has been removed. The principle he describes cannot work unless the head has been reduced.

4. Dr. Compere speaks of congenital dislocation of the hip as though all dislocations are identical. I still believe that there are three distinct primary types of congenital dislocation. Most of our difficulty is encountered in the treatment of the primary anterior type. A position of abduction and internal rotation cannot and will not prevent the head from slipping forward through the defect in the anterior rim of the acetabulum. This we know, because we have tried it in repeated instances. In this type and even in some of the posterior dislocations, some form of reconstruction of the acetabulum will be required, regardless of how long fixation is continued.

5. If femoral torsion, as stated, can be corrected by this prolonged fixation, this represents its principal advantage. However, to accomplish this, the patients are immobilized for approximately one year. By derotational osteotomy, this time can be appreciably diminished. This would seem preferable to me, especially in our clinics, where many patients must travel great distances, and must stay in the hospital until treatment has been completed.

While this principle has a place among our therapeutic measures, unfortunately the treatment of congenital dislocation of the hip is not simple and cannot be covered in generalities, as intimated. Each patient presents an individual problem. We occasionally see a hip which becomes redislocated after treatment has been completed. Fixation for a few months by the method described, which permits mobility of the hip, will frequently ensure permanent stability. To me, this represents its principal value. For this, however, short-leg plaster casts and a crossbar serve the purpose very well. This type of fixation was described by Badgley, in his Presidential Address before this Academy in 1943.

DR. EDWIN W. RYERSON, CHICAGO, ILLINOIS: Several important points have been emphasized in this excellent paper. If all congential dislocations of the hip could be recognized and reduced during the first twelve or fourteen months, the results would be far better than can be achieved in older children. The right-angle "frog" position should be maintained until a competent acetabular rim can be demonstrated by roentgenogram. In bilateral dislocations, the Denis Browne splint will provide excellent abduction after the removal of the plaster-of-Paris spica, and will afford, as Dr. Compere has said, enough freedom of motion to stimulate the development of the joint. It facilitates cleanliness and ease of handling. I have never used it, because for many years I have found that a light, waterproof spica of cellulose acetate is comfortable and efficient.

In unilateral cases, the spica is bivalved and hinged, and the child learns rapidly to walk with a high sole on the normal side. In bilateral cases, the cast is bivalved and held by straps and buckles, as no hinges can be used, and it is astonishing to see how well such children can handle themselves and how comfortably they can sit on chairs and even walk.

I described this method in 1926, in *The Journal of Bone and Joint Surgery*, after using it for more than ten years; but, so far as I know, nobody else has ever tried it.

COMPOUND COMMINUTED FRACTURES INVOLVING THE ELBOW JOINT

Treatment by Resection of the Fragments *

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Observations of battle casualties have revealed that, when compound comminuted fractures involving the elbow joint are treated by resection of the fragments, a stiff, painful elbow with draining sinuses is avoided, and a useful elbow results. The frequent complications of suppurative arthritis and osteomyelitis are aborted. The patient remains ambulatory and his evacuation can be carried out under conditions allowing minimum care. The wounds about the elbow heal rapidly, and early function can be permitted. Unless the fracture is associated with a nerve lesion, no especial after-care is required, and thus the period of hospitalization is reduced.

HISTORICAL BACKGROUND

Resection of the elbow joint has been practised for almost two centuries. According to Ashhurst, a resection of the lower end of the humerus was done by Wainman and by Tyre in 1758 or 1759, and a complete resection of the elbow joint was performed by the elder Moreau in 1794. Park, in 1783, described the surgical approach through a single longitudinal incision parallel with the radial border of the ulna.

Resection after gunshot wounds of the elbow, with compound comminuted fractures involving the joint, was employed extensively during the numerous European wars of the early Nineteenth Century. This is revealed in Table I, which was prepared by Otis. The high mortality from the procedure, 44.5 per cent., was due to inability to control shock and infection, rather than to lack of surgical skill. This is apparent in a report by Burke of an excision of a soldier's elbow joint in the Regimental Field Hospital in Crimea in 1855. The wound was brought together by means of sutures and adhesive plaster; this was followed by extensive swelling. Two sutures were removed and "very copious and exhausting suppuration succeeded". Mr. Burke was "disposed to attribute the supervention of the unpleasant symptoms above mentioned to a constitutional diathesis ill adapted for the receipt of the shock of a severe wound, such as is frequently observed in soldiers after a certain term of military service".

In the American Civil War, Otis reports the results of 626 cases of elbow resection. There was a mortality rate of 23.7 per cent., which was about half the mortality rate of the series reported for the preceding fifty years. The mortality rate during the Civil War from amputation of the upper arm was 23.6 per cent. The lowest mortality observed by Otis (Table II) occurred in the delayed or secondary resection. He stated that the high mortality rate in the intermediary resections was due to the frequent incidence of septicaemic infections and hemorrhage. He pointed out that primary resection was preferable, as the source of infection was attacked and the period of convalescence was shortened. This, he declared, had been emphasized by Esmarch, Langenbeck, and Stromeyer. He claimed excellent results "when the joint ends of either the upper or forearm have been removed after complete exposure of the joint, and the uninjured portions of the articulation have been unmolested".

Fifty years later, in World War I, among the reports of elbow resections reviewed,

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

TABLE I

SHOWING THE RESULTS OF CASES OF SHOT FRACTURE OF THE ELBOW TREATED BY EXCISION ON THE OCCASIONS NAMED AND FROM THE AUTHORITIES QUOTED *

Action, etc.	Total	Recovery	Deaths	Result Unknown	Percentage of Fatality
Revolution in Paris, 1848 (Baudens)	2	1	1	..	50.0
War in Sleswick-Holstein, 1848–50 (Esmarch)	40	34	6	..	15.0
Crimean War, Russian (Hubbenet)	25	7	9	9	56.2
Crimean War, French (Chenu)	4	..	4	..	100.0
Crimean War, British (Matthew)	20	17	3	..	15.0
Italian War, 1859–60 (Demme, Rodolfi)	3	3	..	..	0.0
New Zealand War, 1863–65 (Mouat)	1	1	..	..	0.0
Danish War, 1864 (Loeffler)	43	30	13	..	30.2
Six Weeks' War, 1866 (Beck, Stromeyer, K. Fischer, Maas, Haschek, Berend)	53	43	10	..	18.8
Campaign in Dalmatia, 1869 (Riedl and Ebner)	2	2	..	..	0.0
Franco-German War, 1870–71 (Barthelmess and Merkel, Beck, Bergmann, Billroth, G. Fischer, H. Fischer, Goltdammer, Graf, Herrgott, Kirchner, Koch, Langenbeck, Lossen, Lücke, MacCormac, Mayer, Ott, Rupprecht, Schaeffer, Schinzinger, Schüller, Socin, Steinberg, Stoll)	183	135	48	..	26.2
Franco-German War, 1870–71, French (Chenu)	212	48	164	..	77.3
Aggregates	588	321	258	9	44.5

* *Taken from* Otis[5], p. 901.

four pertinent observations were outstanding. First, there were no reported mortalities. This was attributed to the prevalent use of Dakin's irrigation and of gauze packing in the wounds. Second, while primary or secondary resections were usually favored, Swan contended that there was no additional risk in intermediate resections. This he attributed to his use of mixed polyvalent streptococcus and proteus vaccine in all cases. Third, although it was universally conceded that the wounds be left open after excision, Shepherd advocated partial closure of less severe wounds and complete closure of the early wounds, after they had been excised and "bipped" [treated with bismuth iodoform paraffin paste]. Fourth, there was more conservatism in the amount of bone excised. Moore stated that the functional result was inversely proportional to the amount of bone removed.

These progressive measures of twenty-five years ago were practically taken for granted in the care of the compound comminuted fractures of the elbow joint which comprise the material for this presentation. The author adopted this method of treating compound comminuted fractures of the elbow joint after observing, over a ten-year period, a

TABLE II

NUMERICAL STATEMENT OF SIX HUNDRED AND TWENTY-SIX CASES OF COMPLETE OR PARTIAL EXCISIONS OF THE BONES OF THE ELBOW JOINT FOR SHOT INJURY †

Operations	Total Cases	Recoveries	Fatal Cases	Result Unknown	Mortality Rate, Determined Cases
Primary	322	250	68	4	21.3
Intermediary	197	127	69	1	35.2
Secondary	54	49	5	..	9.2
Time of operation unknown	53	44	4	5	8.3
Aggregates	626	470	146	10	23.7

† *Taken from* Otis[5], p. 845.

patient of Willard's who had had his elbow blown out with a dynamite charge; and after examining several patients of Buzby's who had had resection, rather than arthroplasty, for ankylosis of the elbow joint.

CLINICAL MATERIAL

During the campaign in the Solomon Islands in 1942, a few patients with extensive compound fractures of the elbow, with marked comminution of the joint surfaces of the humerus, ulna, and radius, were treated from three to ten days after injury by resection of the fragments. Impressive were the subsidence of fever, relief of pain, and diminution of drainage. Unfortunately, no follow-up examinations could be planned for these patients, as they were evacuated from island to island, by ship or plane, until they reached the United States. In the past two years it has been possible to observe twelve patients with compound fractures involving the elbow joint, caused by bullet or shrapnel wounds, in whom the bone fragments were removed from two to six months after injury. Suppurative arthritis with draining wounds existed at the time of operation in every case except Case 2. The patients have been followed from one to seventeen months after operation.

TECHNIQUE

The patient was given a general anaesthetic. The apparatus supporting the elbow was removed, and sterile gauze was placed over the wounds. The entire arm, from finger tips to axilla, was scrubbed with a hand brush and green soap. The hair was shaved. The skin was prepared with ether, alcohol, and merthiolate. A pneumatic cuff, inflated to 212 millimeters of mercury, was used as a tourniquet. A lateral approach to the elbow joint was used. Only the loose fragments of bone were removed; and no resection of intact bone, other than the radial head, was undertaken. The cartilage which covered the bone ends was not removed. In those patients in whom the trochlea was not fragmented, a pannus usually covered most of the cartilaginous surface. Beneath the pannus, the cartilage had lost its normal luster and whiteness; but it was not removed. All granulations and purulent material in the area were swabbed and flushed out as well as possible. Only those metallic particles which were in the field of operation were removed.

The operative incision was closed primarily, except in two patients, where it extended into large granulating wounds. When small wounds lay in the line of incision, they were excised and closed with the incision. No attempt was made to close the second wound or sinus communicating with the elbow. A compression dressing from the finger tips was applied before the tourniquet was released.

In the early cases, a plaster-of-Paris cylinder, extending from fingers to axilla, was believed necessary for immobilization. It was found, however, that the patients were not uncomfortable after the fracture fragments had been removed, so that a simple anterior splint was used for only two weeks. This was followed by a sling. The patient was encouraged to take his arm out of the sling and to discontinue its use entirely after the fourth week. After from four to six weeks, the men went on convalescent leave. During this time, considerable progress in motion was made in every case.

TREATMENT

Sulfonamides were used in the early cases treated on shipboard. Powdered sulfathiazole was sprayed into the wound, and the tablets were given orally. When penicillin became available, the patient was given 20,000 units every two hours for twenty-four hours before operation and for seventy-two hours after operation. Penicillin was given by continuous hypodermoclysis after operation in one case. No particular change was observed in the patient's postoperative course, and psychologically he was very unhappy about the necessity of remaining in bed for three days.

COURSE

Signs of infection in every case cleared rapidly after operation. No patient had a postoperative fever. There were no secondary hemorrhages. When the first dressing was

FIG. 1-A

FIG. 1-B

Case 7. Photographs showing the underlying wound, fifty-one days after injury.

FIG. 1-C

Roentgenograms reveal the extent of comminution of the bones of the elbow joint.

FIG. 1-D

The appearance of the bone ends is shown, 135 days after resection of the fragments.

FIG. 1-E

Photographs indicate the range of elbow motion.

done at two weeks, the wounds were crusted to the dressing. When the dressing had been removed, there was no free drainage from the open wounds or sinuses. The elbow had lost the fusiform swelling and had practically regained its normal contour. The absence of pain was noted. Some of the patients recalled the discomfort they had had when the supporting cast was removed before operation to permit photographs, and they were amazed to move their elbows without pain through a range of from 20 to 30 degrees.

COMPLICATIONS

The complicating injuries included third-degree burns, wounds of the chest, and fractures of the other extremities. The local complicating injury was damage to the radial or ulnar nerve. An injury to the median nerve did not occur in this series of cases. The radial and ulnar nerves were both paralyzed in one patient, but recovery took place spontaneously over a period of six months after the injury. The ulnar nerve alone was involved in four patients; in one, recovery was spontaneous. The radial nerve alone was involved in one patient; there was spontaneous partial recovery. The nerves which failed to recover were explored by members of the Peripheral Nerve Service, and were found to have lost continuity. These nerves were repaired, but sufficient time had not elapsed to report upon the extent of their recovery. No patient suffered an additional nerve injury as a result of the operative resection of the fragments of the elbow joint. A sinus persisted after operation in only one case; after three months, a sequestrum was re-

FIG. 2-A

Case 3. Photograph taken fifty-six days after injury.

FIG. 2-B

Roentgenograms show the appearance of the elbow after resection of the capitellum and head of the radius.

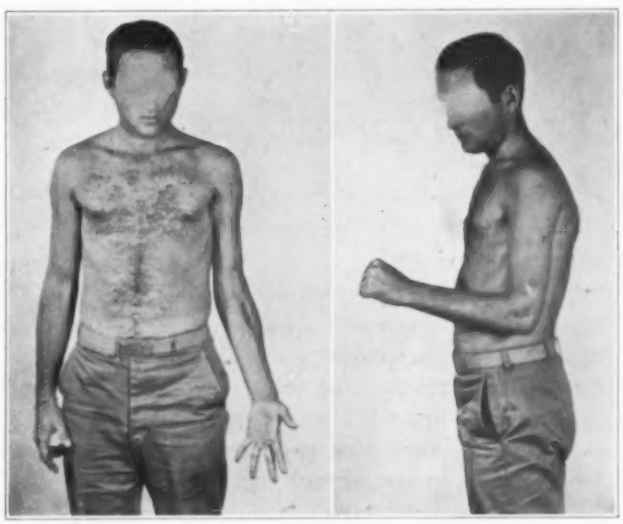

FIG. 2-C

Patient illustrates elbow motion, 113 days after operation.

FIG. 3-A

FIG. 3-B

Case 4. Roentgenograms show the shattered olecranon seventy-six days after injury (Fig. 3-A) and after resection (Fig. 3-B).

FIG. 3-C

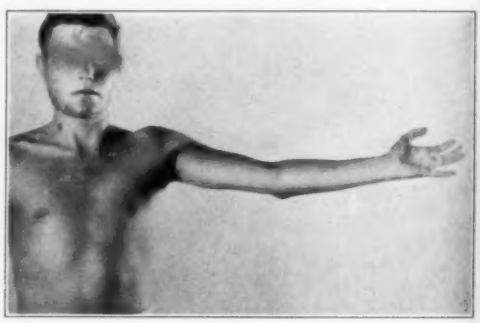

FIG. 3-D

Elbow motion 127 days after operation is shown.

moved. Healing was primary, and no further drainage occurred during four months of additional observation. In three cases the head of the radius was removed within from three to six months after resection to improve active pronation. In these cases there was no joint space, but dense fibrous scar tissue was present between the bone ends. The roentgenographic examination of the resected joints, four or more months after operation, frequently revealed spicule formation about the bone ends. No loss of motion had been observed as a result of these bone changes.

ANALYSIS OF RESULTS

The condition of the injured elbows remained almost stationary until the underlying fragments had been resected. There was little wound repair. A wound, fifty-one days after injury, is shown in Figures 1-A and 1-B. Sixty-six days after resection of the fragments, the wound was completely healed. The regression of infection and the ability to attain function of the elbow were essentially the same, whether the resection was done in the primary, intermediate, or secondary phase. A resection in the primary stage, unless the injury was complicated by a nerve lesion, resulted in a much shorter convalescence. Resection and primary closure of the surgical wound, without regard for phase of injury, was possible with the use of penicillin.

The most important consideration in analysis of the results was the future function of the arm. This was found to depend upon the amount of bone resected (Table III). There were five classes of resection:

1. *Resection of Capitellum and Head of Radius (Three Cases)*

In Case 3 (Figs. 2-A to 2-C) the wound was resected and closed at operation; primary healing resulted. The fragments were resected an average of seventy days after injury in this group. The follow-up, which was made at an average of sixty-seven days, revealed lateral stability in extension or flexion; a flexion deformity of from 10 to 20 degrees; flexion against resistance to more than a right angle; no interference with the power of extension; and a relatively good range of supination and pronation.

2. *Resection of the Olecranon*

Case 4 (Figs. 3-A to 3-D) was the only case in this group. The fragments were resected and the ulnar nerve was transplanted seventy-six days after injury. The follow-up at 120 days revealed 10 degrees of lateral instability when the muscles were relaxed, no flexion deformity, and flexion against resistance to more than a right angle. Extension of the forearm against gravity was possible only to 20 degrees; but the arm could be abducted with the elbow in extension, and a fourteen-pound weight could be raised five inches above the head. The range of both supination and pronation was within 30 degrees of normal, although the head of the radius was not resected.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 5. Condition of wound forty-five days after injury. The wound was resected and closed at operation. Primary healing took place.
Fig. 4-B: Patient demonstrates range of motion fifty-five days after operation.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Roentgenographic appearance of elbow forty-five days after injury.
Fig. 4-D: Roentgenograms taken 127 days after the resection.

FIG. 5-A

Case 9. Photograph taken seventy-one days after injury. The elbow has a draining sinus and requires support.

FIG. 5-B

Patient demonstrates range of motion fifty-eight days after operation.

FIG. 5-C

Before operation.

FIG. 5-D

After resection.

3. *Resection of the Proximal End of the Ulna and Radius*

The one patient in this group (Case 5) had complete ulnar paralysis (Figs. 4-A to 4-D). The fragments were resected forty-five days after injury. The follow-up at 127 days revealed 25 degrees of lateral instability when the muscles were relaxed, a flexion deformity of 15 degrees, and flexion against light resistance to 90 degrees. Extension of the forearm against gravity was possible to 30 degrees. The arm could be abducted with the elbow in extension. Supination was possible to 30 degrees, and pronation to 10 degrees.

4. *Resection of the Condyles of the Humerus and the Head of the Radius*

There were three cases in this group. In two cases the fragments were resected not quite two months after injury, but in one patient (Case 8) resection was done six months after injury. A partial radial paralysis existed in Case 8. The patient also had a persistent sinus after operation, and on the 114th day a sequestrum was removed. The wound was still closed after four additional months. The most extensive wound was present in Case 7 (Figs. 1-A to 1-E); it was healed sixty-six days after operation. The head of the radius and the overlying scar were resected secondarily on the 126th day after operation, with resultant improvement in supination and pronation.

TABLE III

POSTOPERATIVE FUNCTION

Operative Resection	Case	Days After Operation	Days After Injury	Range of Flexion (*Degrees*)	Supination (*Degrees*)	Pronation (*Degrees*)	Abduction with Elbow Extended (*Degrees*)	Elevation with Elbow Extended (*Degrees*)	Extension against Gravity (*Degrees*)
Capitellum and head of radius	1, R.W.A.	60	125	160 to 30	90	90	90	90	90
	2, R.L.H.	30	120	170 to 30	90	60	90	90	90
	3, R.A.W.	113	169	160 to 80	60	20	90	90	90
Olecranon	4, W.A.B.	120	196	180 to 70	75	60	90	0	20
Proximal end of ulna and radius	5, R.F.C.	127	172	175 to 90	30	10	90	0	30
Condyles of humerus and head of radius	6, F.R.C.	90	169	205 to 30	90	20	90	0	25
	7, J.A.B.	135	186	190 to 30	65	0	90	0	10
	8, R.C.F.	248	445	190 to 80	10	20	60	0	25
Condyles of humerus, olecranon, and head of radius	9, H.E.G.	58	139	185 to 30	10	0	90	0	5
	10, J.R.W.	120	237	180 to 90	65	− 10	0	0	10
	11, L.A.K.	277	279	190 to 30	45	0	0	0	20
	12, C.B.	510	539	190 to 70	70	20	0	0	30

The follow-up of this group was made at an average of 200 days, and revealed from 30 to 45 degrees of lateral instability; no flexion deformity; but from 10 to 25 degrees of hyperextension. With five pounds of resistance, flexion was possible to more than a right angle; extension of the forearm against gravity was possible from 10 to 25 degrees, and the arm could be abducted with the elbow extended.

5. *Resection of the Condyles of the Humerus, the Olecranon, and the Head of the Radius*

There were four cases in this group. Case 11 was one of ulnar paralysis. A primary resection had been done. The patient's arm was flail until after a secondary resection of the head of the radius and the overlying scar had been performed on the 215th day. His improvement, as shown in Table III, was remarkable. In Case 12 a resection of the fragments was carried out on the twenty-ninth day. Although the patient was seen after injury, his complicating chest wound, hemorrhage, and shock did not permit immediate operation upon the elbow. He had a partial residual ulnar paralysis from his brachial wound. Because of a two-inch gap between the bone ends, a supination deformity, and lateral instability of almost 90 degrees in either direction, removal of the head of the radius and construction of lateral ligaments and expansion of the triceps with fascia lata were done on the 198th day after operation. In Case 10 a resection was performed on the 117th day after injury. The patient had a large granulating wound, three inches in diameter, over the medial surface; and a partial ulnar paralysis. The head of the radius was not removed at the time of operation, and a supination deformity resulted. In Case 9 (Figs. 5-A to 5-D) a resection was done eighty-one days after injury.

The follow-up of these patients, averaging 239 days after resection, revealed as much as 60 degrees of lateral instability; hyperextension against gravity of 10 degrees; and flexion against the resistance of a glass of water to 90 degrees or more. The initiation of this flexion was accomplished by eliminating the force of gravity. Extension of the forearm against gravity was from 5 to 30 degrees. Only in Case 9 could the arm be abducted

with the elbow extended. Pronation was possible to 20 degrees in one case. All of the patients had active motion at the distal humeroradial joint.

SUMMARY

Surgical resection of the fragments following a compound comminuted fracture involving the elbow joint was without major complications. The procedure was carried out in the presence of open draining wounds, in the primary, intermediate, or secondary phase of the injury. The patient was ambulatory from the first day after operation. Elbow motion was started after two weeks, and no mechanical support other than a sling was used.

The operative wound was closed primarily when penicillin was used. The temperature, pain, fusiform swelling, and drainage subsided after the resection. The operative wound healed primarily within two weeks. The healing time of the wound of injury depended upon the extent of soft-tissue damage.

The functional result was better when there was little loss of bone substance. If the trochlear surfaces of the humerus and ulna had been preserved, the elbow joint to all intents and purposes functioned normally. With the loss of the olecranon or the condyles of the humerus, the power of extension was sacrificed. The loss of the trochlear surface of the ulna added lateral instability in relaxation and slight loss of flexion power. The loss of the condyles of the humerus, alone or in conjunction with the proximal portions of the ulna and radius, resulted in about the same degree of additional loss in power of flexion against resistance and in further instability of the joint. Lateral instability of more than 45 degrees resulted in loss of ability to abduct the extended arm. Resection of two or three inches of the humerus resulted in a longer period before the power of flexion was regained, and in the most unstable joints. Even with a plastic repair, three inches was considered the greatest resection possible. The ability actively to supinate and pronate the forearm was, with one exception, dependent upon the absence of the head of the radius. Three patients were improved by a secondary operative removal of the head of the radius. The only patient who had a supination deformity failed to have the head of the radius removed. In all cases, pronation was more difficult to obtain than supination. A joint space did not reform at the site of the resected elbow, but fibrous scar tissue persisted between the bone ends six months after operation. Following operation, the formation of bone spicules at the bone ends was observed, but this had not resulted in loss of function.

REFERENCES

1. Ashhurst, J., Jr.: The Principles and Practice of Surgery, Ed. 2. Philadelphia, Henry C. Lea, 1878.
2. Burke: Excision of the Elbow-Joint, in a Soldier of the 3rd Regiment, for a Compound Comminuted Fracture of the Bones of the Articulation, from a Shell; Recovery with a Useful Arm. Lancet, **2**: 462, 1856.
3. Buzby, B. F.: End-Results of Excision of the Elbow. Ann. Surg., **103**: 625–634, 1936.
4. Moore, A. E.: The Results of Primary Excision for Wounds of the Elbow-Joint. British J. Surg., **6**: 265–272, 1918–19.
5. Otis, G. A.: The Medical and Surgical History of the War of the Rebellion, Part II, Surgical History, Vol. II, p. 845. Washington, Government Printing Office, 1876.
6. Park, H.: An Account of a New Method of Treating Diseases of the Joints of the Knee and Elbow, p. 45. London, J. Johnson, 1783.
7. Shepherd, W. M.: Gunshot Injuries of the Elbow-Joint: Treatment by Early Excision. British Med. J., **1**: 149, 1918.
8. Swan, R. H. J.: The Treatment of Severe Infected Gunshot Injuries of the Shoulder and Elbow Joints. Early Excision to Secure Mobility. Lancet, **1**: 524–529, 1917.
9. Swan, R. H. J.: Primary Excision of Gunshot Wounds of the Elbow-Joint. British Med. J., **2**: 704–705, 1917.
10. Swan, R. H. J.: Primary Excision of Gunshot Wounds of the Elbow-Joint. British Med. J., **1**: 134–135, 1918.
11. Willard, DeForest P.: Personal communication, 1930.

DISCUSSION

Dr. Jean Verbrugge, Antwerp, Belgium: I subscribe without hesitation to the main ideas contained in Dr. Nicholson's paper, and congratulate him on his interesting historical data. I had the opportunity and the privilege of observing some of his excellent results, at the United States Naval Hospital in Oakland.

The main principle underlying the treatment of war injuries to the elbow lies in the well-known and widely accepted principle of débridement. It is commonly recognized that débridement should be performed thoroughly at the level of the injured muscles and fascia; it is also known that one should be more parsimonious with the amount of skin resected. But what about the bones?

When the injury is at the level of a diaphysis, every effort should be made to preserve as many fragments as possible, even at the risk of replacing the fragments of bone in their original position after curettage, whenever possible.

When the injury affects a joint, however, especially in the upper extremity and still more especially the elbow joint, where ankylosis takes place so easily and interferes with function, bone may and often should be resected more freely. As Dr. Nicholson says, it will bring about faster healing and result in a shortened period of treatment and in a quick and better restoration of function.

I would not fear as much as Dr. Nicholson does resection of the lower end of the humerus. Of course, cases differ very much from one another, but I would be tempted to divide them into two groups: (1) those in which only one bone has been touched and the joint itself is fairly well preserved; and (2) those in which the fracture is comminuted and involves several bones and the joint space. In the first group, I would resect the injured fragments, as Dr. Nicholson does; and suggest, if the operation is performed very early, a thorough cleaning of the wound and cauterization of the raw surfaces of bone, avoiding suture of the fascia, so as to prevent calcification. In the second group, I would not hesitate to resort to the classic resection of the elbow, including the lower end of the humerus.

This prompts me to make the following comments:

1. The name of Ollier should be mentioned in connection with resection of the elbow. His incision *"en bayonette"* gives an excellent approach to the joint.

2. Subperiosteal resection should be employed, because this technique will prevent hemorrhage, and will respect, as much as possible, the attachments of the muscles and the capsule.

3. Use of scraping instruments, like a sharp periosteal elevator or a curette, should be avoided as much as possible.

4. The head of the radius should be excised only if it has been damaged; in that case, its excision is imperative.

5. Immobilization by a plaster cast first, and a bivalved cast later, should be prolonged for many weeks and up to three months. The period of immobilization depends upon the extensiveness of the resection and the condition of the periarticular structures.

6. I cannot share Dr. Nicholson's assurance about intermediate operation, when infection is present. The danger of hemorrhage is then prevalent; the bone is thin; the veins are phlebitic; and the soft tissues often are diseased. War surgery, however, is often a matter of opportunism and judgment.

7. From observing the late results, it is often surprising to note how much strength and useful power can be secured in an unstable elbow, when it is flexed beyond the right angle. Its aesthetic appearance may not be satisfactory, but it undoubtedly surpasses in value a stiff joint.

Dr. Nicholson mentions the conclusions arrived at after World War I. His paper and the experiences of other military surgeons in World War II prove that the methods of treatment of compound comminuted fractures of the elbow will have to be revised.

THE TREATMENT OF CHRONIC OSTEOMYELITIS BY THE USE OF MUSCLE TRANSPLANT OR ILIAC GRAFT

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The purpose of this paper is to present the method used in treating sixty-four separate foci of chronic osteomyelitis in sixty-one patients during the past sixteen months. Practically all areas of the skeleton have been affected (Fig. 1), including four cases which involved major joints with suppurative arthritis. Healing occurred in a high percentage of cases within ten weeks, and there have been no recurrences, pathological fractures, or fatalities. The average period of observation has been seven and one-half months. All patients were males between eighteen and thirty-seven years of age. The disease was due to the usual causes, being hematogenous in four (Cases 13, 14, 15, and 38 in Group *A*), secondary to operative infection in six (Cases 21, 26, 27, 28, 39, and 40 in Group *A*), and secondary to infected compound fractures (from falls, vehicular accidents, or gunshot wounds) in the remainder. The chronic granulomata of bone are not included in this series, although this method should be applicable in selected cases of this type of chronic bone infection.

The management of chronic pyogenic osteomyelitis has always been highly unsatisfactory, and is one of the most distressing problems in the field of orthopaedic surgery. Whether it is secondary to infected compound fractures or to the catastrophe of operative infection, or whether it is hematogenous in origin, the bone infection has been difficult to eradicate. Too often it results in crippling from stiffened joints, atrophied muscles, recurrence of the disease, pathological fractures, and occasionally from delayed union or nonunion of infected fractures. The chronic sepsis enforces an interminable delay in undertaking reconstructive surgery. Frequently, it is the direct cause of secondary anaemia and the rare, but serious, complication of amyloid degeneration. Nephrolithiasis is not an uncommon finding in these debilitated patients, particularly when prolonged recumbency is necessarily enforced. If there is a lesion of a peripheral nerve, associated with a compound fracture—as is frequently seen, due to the perforating, high-speed missiles of modern warfare—it is imperative to clear up infection early, in order that definitive neurosurgical procedures may be accomplished without delay. The longer the time interval between laceration of nerve tissue and surgical repair, the poorer is the prognosis for recovery of the paralyzed muscle groups.

The advent of the bacteriostatic drugs, particularly penicillin, at first gave promise of a possible cure. However, it soon became apparent that penicillin, like the sulfonamides, would not be effective, either systemically or locally, in tissues with little or no vascularity. Such tissues include sinus tracts with the surrounding cuff of dense scar tissue, bone abscesses containing chronically infected granulation tissue (which in the process of healing will become dense scar tissue), sequestra, and the area of eburnated bone which is frequently found at sites of chronic osteomyelitis. Furthermore, the newer bacteriostatic drugs, such as streptomycin, could hardly be expected to accomplish better results after chronic bone infection has become established. The value of these drugs as adjuvants to the surgical treatment of osteomyelitis is considerable, however, since more radical surgery is possible without danger of the localized infection becoming disseminated or assuming an invasive character. In all of the cases reported here, penicillin only was used, as it is less toxic than the sulfonamides. Streptomycin was not available for trial. In most instances (Table II) some bacterial species present were not sensitive to penicillin. How-

ever, penicillin was used systemically and locally, as it was felt that, if the usual invasive pathogens could be controlled by the bacteriostatic agent, the remaining organisms would be eliminated by the resistance of the host.

In view of these considerations, it was clear that some method of excision of all infected and potentially infected (hypovascular) tissue, which would result in prompt and complete healing with little or no chance of recurrence, was vitally necessary. This would allow early reconstructive surgery, including correction of deformity, bone graft, tenoplasty, and repair of lesions of the peripheral nerves and vascular lesions. Restoration of function would be greatly accelerated. The complications and sequelae mentioned would be reduced markedly, and the tremendous economic loss which chronic osteomyelitis has always exacted in the past would be curtailed.

Since healing depends to a great extent upon good vascularity of the tissues to be healed, it seemed apparent that simply removing sequestra and curetting the walls of the bone abscesses and sinus tracts would lead in too many instances to incomplete healing, subsequent breakdown, and recurrent drainage. If a radical excision of all avascular and infected tissue could be accomplished, however, and if the dead space so formed could be obliterated and the wound closed, then all the factors for prompt healing would be present. The rate of recurrence should be exceedingly small with such meticulous removal of all tissue which could act as a reservoir of potential infection. This very situation has long been noted in osteomyelitis of the ribs and fibulae. In these areas, excision of that portion of the bone containing the infection is almost invariably followed by prompt healing. This is due to the fact that, once the section of bone containing the diseased focus has been removed, the adjacent viable and vascular (and consequently infection-resistant) muscles fold into the defect, obliterating the dead space, and healing takes place.

The crux of the entire situation—the success or failure of a quick method of permanently healing a focus of

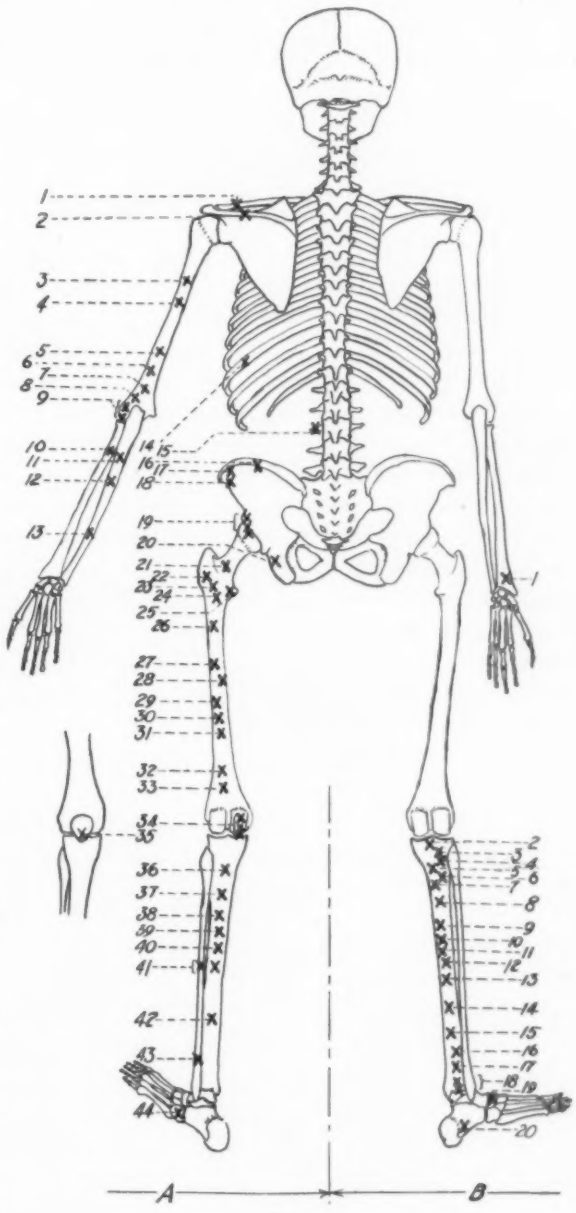

FIG. 1

Fig. 1: Distribution of chronic osteomyelitis in the sixty-four instances reported. Numbers used for the cases in the text are based on this diagram.

A: The areas on the left (Group *A*) show the skeletal level of all foci which were treated by excision and obliteration of the defect with viable muscle.

B: The areas on the right (Group *B*) show the skeletal level of all foci which were treated by excision and filling of the defect with cancellous iliac bone.

TABLE I

THE INCIDENCE OF BONES INVOLVED IN THIS SERIES *

	Number of Bones Involved	Per Cent.
Tibia	24	36.4
Femur	15	22.7
Humerus	7	10.6
Radius or ulna	5	7.6
Pelvis	5	7.6
Tarsals	3	4.6
Shoulder girdle	2	3.0
Ribs and transverse processes of vertebrae	2	3.0
Fibula	2	3.0
Patella	1	1.5
Totals	66	100.0

* The apparent numerical discrepancy is due to the fact that both the tibia and fibula were involved in Case *A*-41, and both the ilium and the head of the femur in Case *A*-19.

chronic osteomyelitis—therefore depends upon the successful obliteration of the dead space, as well as upon the complete excision of the diseased tissues.

OBLITERATING THE DEFECT WITH MUSCLE

For the past several years, principally since the advent of the sulfonamides, complete excision of foci of chronic osteomyelitis, with either partial or complete closure, has been recommended in the treatment of this disease. More recently, obliterating such bone defects by exteriorization (skin grafts applied directly to the defect) has again been advocated, and good results have been reported. However, radical excision of diseased tissue, filling any deep, rigid-walled bone defect by a viable muscle pedicle, as suggested by Starr and Mercer; and closure of the wound appear to be a logical approach to this problem. Consequently, it was decided that such a procedure would be the method of choice in treating chronic osteomyelitis of any area of the skeleton, provided that, surrounding the bone focus, there was sufficient muscle tissue which could safely be utilized to fill the defect adequately. Such skeletal areas would include the scapula, clavicle, humerus, forearm bones (except the radial styloid), and metacarpals in the upper extremity; the pelvis, femur, fibula, and metatarsals (and, in selected instances, the tibia), in the lower extremity; and the vertebral processes and ribs. In these areas the procedure has been to radically excise the avascular and infected tissue, fill the bone defect by viable muscle, and do a loose primary or secondary suture, even if this meant leaving the extremity flail, but clean surgically. In a few pertinent instances, this has allowed early repair of associated

TABLE II

MICRO-ORGANISMS RECOVERED FROM THE WOUNDS IN TWENTY CASES OF COMPOUND FRACTURE COMPLICATED BY CHRONIC OSTEOMYELITIS *

	Cases	Per Cent.
Pseudomonas aeruginosa (*Bacillus pyocyaneus*)	14	70
Staphylococcus aureus	10	50
Staphylococcus albus (facultative anaerobe)	8	40
Staphylococcus aureus (hemolytic)	7	35
Escherichia coli and paracolon species	6	30
Proteus species	6	30
Diphtheroids	3	15
Aerobacter aerogenes	3	15
Streptococcus viridans	3	15
Streptococcus pyogenes (*Streptococcus haemolyticus*)	3	15
Streptococcus species (non-hemolytic)	2	10

* With one exception, all wounds contained multiple species.

FIG. 2-A
Case *A*-8.

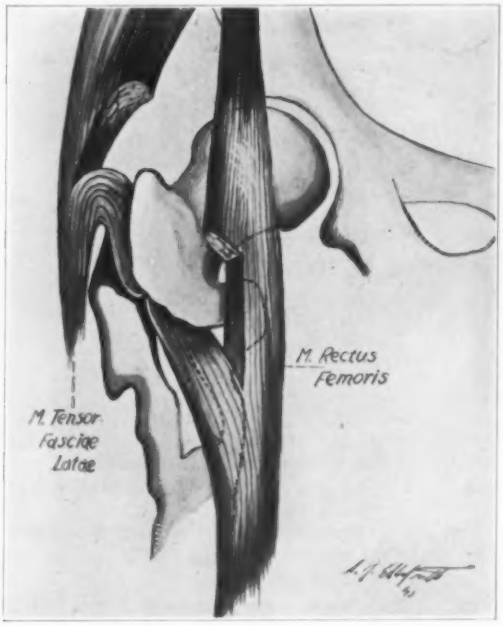

FIG. 2-B
Case *A*-23.

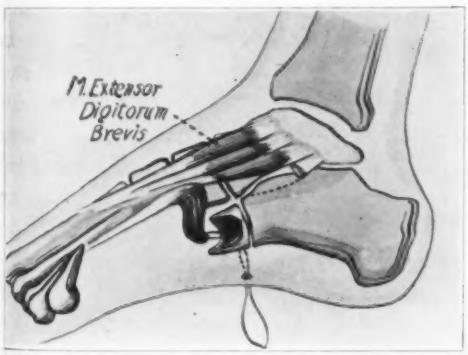

FIG. 2-C
Case *A*-44.

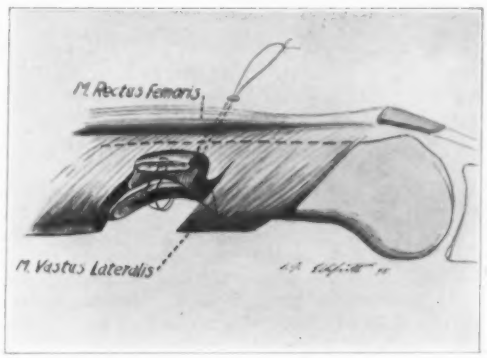

FIG. 2-D
Case *A*-32.

Examples of muscle pedicles used in filling bone defects.

peripheral-nerve lesions; the false motion and shortening of the extremity favor easy approximation of the nerve, without tension.

Closure of the skin and superficial fascia over the wound should be done, even if it is necessary for the operator to do a relaxing incision on one or both sides of the original wound, displacing the skin and subcutaneous tissue so that closure may be made without tension, and then covering the skin defect so formed by a split-thickness skin graft. In many instances, particularly in the lower extremities, later bone-grafting will be required to give the involved bone sufficient strength to fulfill its function of weight-bearing.

The routine procedure includes an evaluation of the patient's general condition and a study of the local pathological conditions. Wound cultures are done routinely, although the organisms found have in no instance caused a change of plan. The ordinary roentgenographic studies are made. Then, after lipiodol injection of the sinuses, stereoscopic

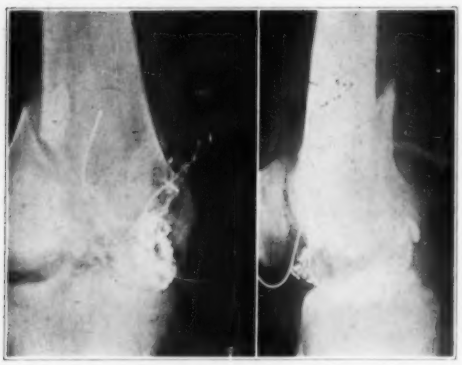

FIG. 3-A

FIG. 3-B

Case *A*-34. Patient sustained a compound T fracture of the femoral condyles in a rock slide on February 26, 1945, with resultant chronic osteomyelitis of the medial condyle and a purulent arthritis of the knee joint. Excision of all devitalized and infected tissue and arthrodesis were performed on July 20. The surgical wound healed in fifteen days; this terminated a five-month period of persistent purulent drainage.

Fig. 3-A: Preoperative lipiodol study was made on May 31, 1945.

Fig. 3-B: Postoperative roentgenograms, taken on October 10, 1945. Clinically, the arthrodesis is secure.

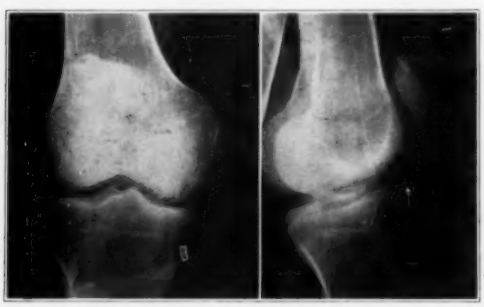

FIG. 4-A

FIG. 4-B

Case *A*-35. Patient sustained a perforating gunshot wound of the right knee on December 15, 1944, with loss of anterior soft tissues, and a compound fracture of the lower pole of the right patella, with resultant chronic osteomyelitis. Excision, patellectomy, and plastic closure of the wound were performed on January 16, 1945. The surgical wound healed in eighteen days; this terminated one month of mild purulent drainage. Eight months after operation there was 25 degrees of painless weight-bearing motion in the knee joint.

Fig. 4-A: Roentgenograms taken on January 15, 1945.

Fig. 4-B: Roentgenograms taken on September 13, 1945, eight months after operation.

views are taken to show the extent and ramification of such tracts. The patient is placed on a high-protein diet, supplemented by a high vitamin intake, with replacement of whole blood and plasma as necessary.

At the optimum time, as early as possible, the patient is operated upon. In so far as possible, a pressure-cuff tourniquet is employed. Methylene blue is injected into all sinus tracts under slight pressure; this aids *en bloc* excision by delineating the tortuous, and often multiple, sinus tracts. An appropriate surgical approach is made, which should always extend well into normal tissue, both proximal and distal to the diseased condition. This is essential, not only for complete visualization of the diseased tissue, but because peripheral nerves and important vessels must be isolated above and below the pathological process in order to preserve their integrity while the operator proceeds with the radical dissection. Also, such exposure is necessary for the proper selection of a portion of muscle to be sacrificed, if needed, by forming it into a pedicle. This is done in such a manner that the innervation and blood supply of the donor muscle and the blood supply of the pedicle will not

Case *A*-19. Patient sustained a perforating gunshot wound in the region of the left hip on August 8, 1944. This caused an incomplete femoral-nerve lesion and a compound fracture of the head of the left femur and adjacent acetabulum, with resultant chronic osteomyelitis and purulent arthritis of the hip joint. Excision and arthrodesis were performed on November 24, 1944. The wound was partially closed, and had healed by second intention on the twentieth day after operation, terminating four months of constant purulent drainage. Clinically, the hip fusion was solid in four months.

Fig. 5-A: Preoperative anteroposterior roentgenogram of left hip, taken on October 7, 1944.

Fig. 5-B: Lipiodol study, made on October 28, 1945.

Fig. 5-C: Roentgenogram, taken on August 1, 1945, shows intra-articular bony fusion.

Fig. 5-D: Photograph of the operative site in November 1945, one year after operation.

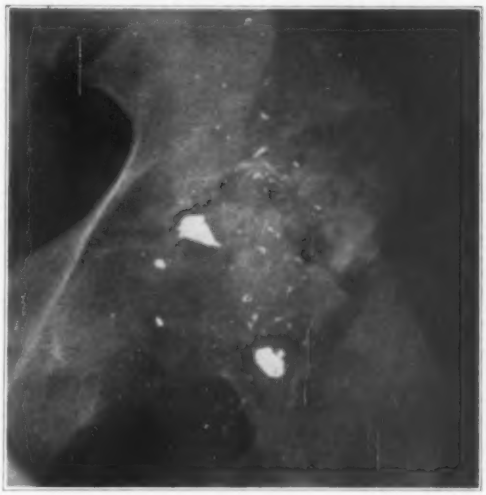

FIG. 5-A

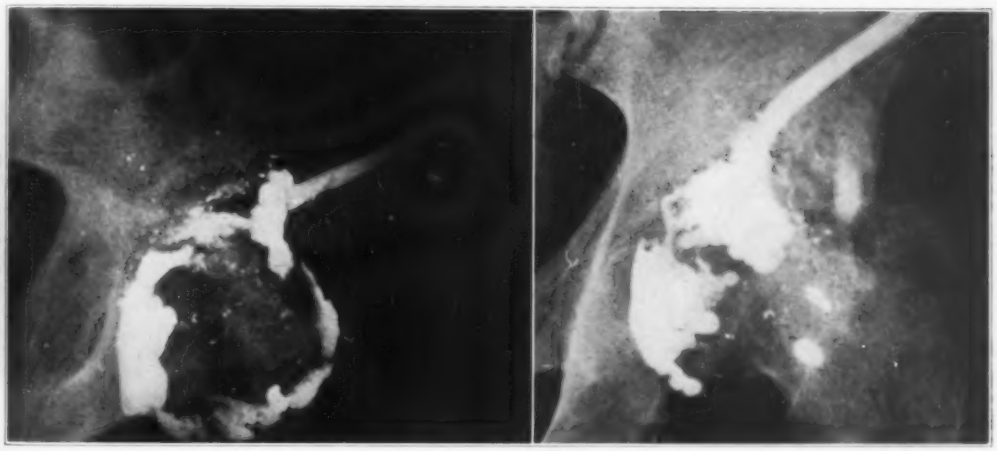

FIG. 5-B

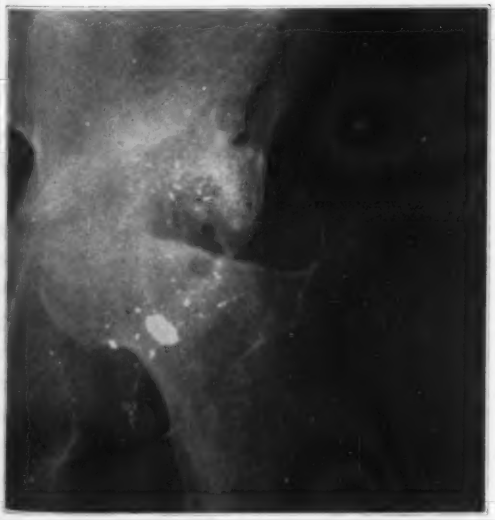

FIG. 5-C

FIG. 5-D

be jeopardized; the object is to ensure minimum interference with function of the part and a viable pedicle. All abnormal tissue—sinus tracts and infected granulation tissue, sequestra, eburnated and abnormal bone—and foreign bodies, if involved, are removed radically so that all remaining tissue appears normal and has good vascularity. The tourniquet is then released and hemostasis is obtained. The bone defect, if shallow, will be obliterated by slight displacement of the surrounding muscles; if deep, a muscle pedicle is formed and sutured into the defect (Figs. 2-A to 2-D). Deep vertical mattress sutures of 0.009 stainless-steel wire are placed, and the wound edges are lightly approximated.

FIG. 6-A

Case *A-27*. Patient sustained a compound, comminuted fracture of the left femoral shaft, with resultant chronic osteomyelitis, caused by a ricocheting bullet on July 5, 1944. Excision was performed on January 10, 1945. The wound healed completely after eight weeks of thin serous drainage from one sinus; this terminated six months of constant copious purulent discharge.

Fig. 6-A: Lipiodol study on December 15, 1944, showing the extent of the bone defect and the metallic foreign bodies.

Fig. 6-B: Anteroposterior and lateral roentgenograms taken on September 27, 1945. The union does not appear to be solid, although the patient had been ambulatory in an ischial weight-bearing brace for two months, without untoward symptoms.

Fig. 6-C: The appearance of the operative site in November 1945, showing the extent of the surgical approach made in order to obtain adequate exposure. At this time, ten months after operation, there is 95 degrees of painless, active motion of the knee joint from the extended position.

FIG. 6-B

FIG. 6-C

FIG. 7-A

FIG. 7-B

Case *A*-33. A shell fragment perforated the lower thigh on April 16, 1944, and the patient sustained a compound, severely comminuted fracture of the lower femur, with resultant chronic osteomyelitis. Alignment was maintained by skeletal traction, and partial bony union occurred. Surgical excision was performed on October 16, 1944, and the wound healed in four weeks; this terminated seven months of mild purulent discharge. In September 1945, eleven months after operation, there was shortening of one and one-quarter inches and 105 degrees of painless knee motion from the extended position.

Fig. 7-A: Lipiodol study made on October 7, 1944.

Fig. 7-B: Roentgenograms taken on August 20, 1945.

A direct or an eccentrically placed drain is removed in forty-eight hours. A few wounds have been closed by secondary suture five to seven days after excision of infected tissue. Appropriate plaster-cast immobilization is applied, as indicated. All patients received penicillin intramuscularly for three weeks, and no sulfonamides were used. The initial dose of 25,000 units of penicillin is administered at the time of operation and repeated every three hours for two weeks. During the third week the dosage is gradually decreased and

FIG. 8-A

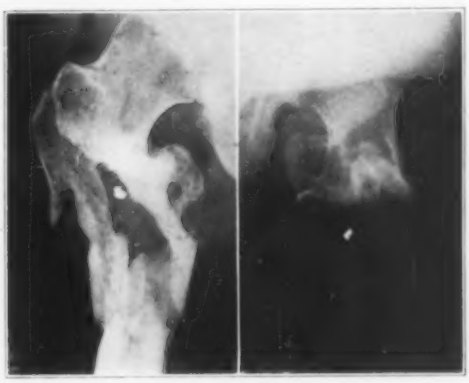

FIG. 8-B

Case *A*-23. Patient sustained a gunshot wound of the right hip on April 12, 1945, causing a complete lesion of the sciatic nerve and a compound, comminuted fracture of the right trochanter, with resultant chronic osteomyelitis. Excision and muscle-pedicle transplant (Fig. 2-B) were performed September 5, 1945. The wound healed *per primam* on the twelfth day after operation, after five months of moderate purulent drainage.

Fig. 8-A: Preoperative lipiodol study made on August 23, 1945.

Fig. 8-B: Postoperative roentgenograms taken on October 5, 1945.

the time interval is increased, until the patient receives 10,000 units every six hours on th twentieth and twenty-first days.

Forty-four foci of infection in forty-two patients have been treated by this metho Good results were considered to have been obtained in forty-three; there was only on failure in which drainage persisted, and this was healed by a second excision. The averag period of drainage prior to operation was twenty weeks; after operation it was three an one-half weeks. Twenty-one wounds were healed completely at the time of first inspec tion,—usually ten to fifteen days after operation. Of the remaining twenty-three patient in all but three the wounds had healed completely within five weeks; these three showed decreasing amount of serous exudate for eight weeks, with no recurrence after five or si months of activity.

The one failure (Case *A*-26) was due to incomplete removal of eburnated bone. A the time of the first excision there was some question as to the advisability of removing small projection of the proximal femoral fragment, which was somewhat eburnated. A the time of the second excision it was found that this area had subsequently become seques trated and was the cause of the continued drainage. Such a finding emphasizes the neces sity for radical excision.

FIG. 9-A

In four instances there wa involvement of a major joint with suppurative arthritis. On of these patients (Case *A*-34 had chronic osteomyelitis of th entire medial condyle of the fe mur, with suppurative arthriti of the knee joint, secondary t a compound T fracture of th femoral condyles, which ha been sustained in a rock slide Adequate exposure was obtained through the medial peripatella

FIG. 9-B

FIG. 9-C

Case *A*-44. Patient sustained a gunshot wound of the left foot on October 6, 1944, causing a compound, comminuted fracture of the cuboid tarsal and the third, fourth, and fifth metatarsals; there was loss of substance, with resultant chronic osteomyelitis. Excision and muscle-pedicle transplant (Fig. 2-C) were performed on February 16, 1945. The wound healed in fourteen days; this terminated a continuous mild purulent exudate of four months' duration. In September 1945, seven months after operation, the walking gait was normal, but running disclosed a limp.

Fig. 9-A: Preoperative roentgenogram taken on December 4, 1944, through a plaster cast, showing diffuse osteomyelitis of the cuboid tarsal.

Figs. 9-B and 9-C: Postoperative roentgenograms taken on July 17, 1945, five months after operation.

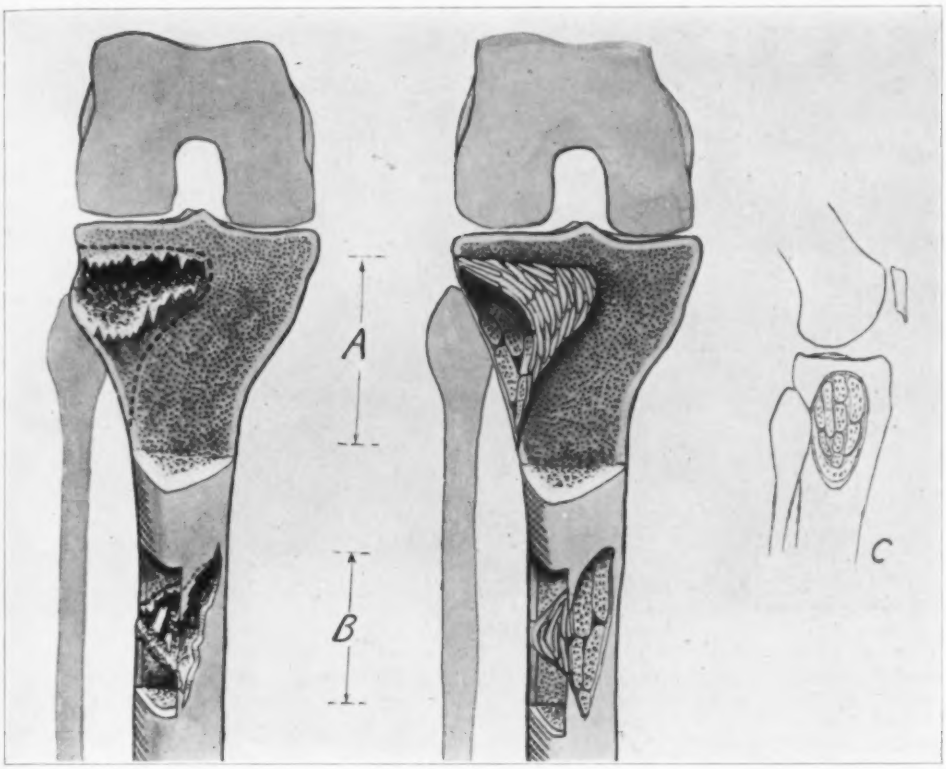

FIG. 10

Shows two typical defects, before and after excision and iliac-bone graft.
A: Coronal section of a large defect and detail of "bricking-in" the iliac chips.
B: Shows partial coronal section.
C: Sketch of lateral view, showing the surface of the grafted area.

approach. Excision was carried out as outlined, with removal of all necrotic tissue, including most of the medial condyle. (The cruciate ligaments and menisci could be identified by anatomical location only.) The joint was leveled by ostectomy of the lateral femoral condyle. All the remaining articular cartilage was excised, and the part was immobilized in a spica cast. The wound had completely healed in two weeks, at the time of the first dressing, and has so remained (Figs. 3-A and 3-B).

The second patient (Case *A*-35, Figs. 4-A and 4-B) had chronic osteomyelitis of the right patella; the lower pole of the patella, the origin of the patellar ligament, and the anterior soft tissues had been shot away five weeks before. Upon removal of the granulation tissue, the articular cartilage of the femoral condyles presented itself; and, after patellectomy, inspissated pus was observed in the folds of the suprapatellar pouch. Smear and culture showed *Escherichia coli*. The joint was thoroughly irrigated with two liters of normal saline; and fifty cubic centimeters of penicillin solution (500 units per cubic centimeter) was instilled. Plastic closure of the skin and superficial fascia was accomplished. Healing was complete within three weeks. Six months after operation there was 25 degrees of painless motion, active and passive, from the extended position.

The third patient (Case *A*-19) had chronic osteomyelitis of the head of the left femur and the adjacent acetabulum, with suppurative arthritis of the hip joint, secondary to a perforating bullet wound (Figs. 5-A to 5-D). Exposure was made through the lateral approach. The roof of the acetabulum and about two thirds of the superior portion of the femoral head were excised. As much of the remaining articular cartilage as could be reached without dislocating the hip was removed, and the dead space was partially oblit-

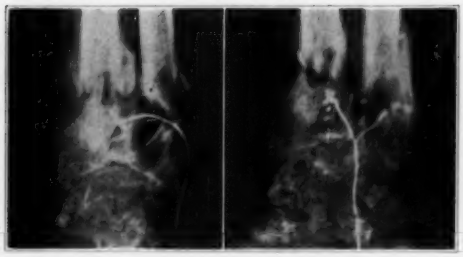

FIG. 11-A

FIG. 11-B

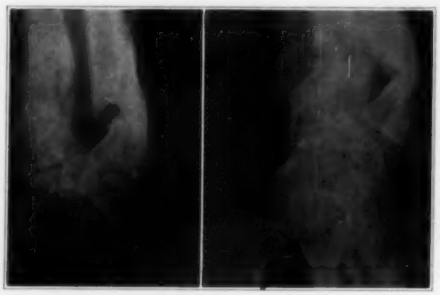

FIG. 11-C

FIG. 11-D

Case *B*-1. A shell fragment penetrated the dorsum of the right wrist on January 20, 1945, with loss of soft tissue, including the extensor tendons to the fingers, and a compound, comminuted fracture of the right lower radius and ulna, with resultant chronic osteomyelitis of the radius. The infected bone was excised, a penicillin pack was inserted into the defect, and an abdominal-skin pedicle was prepared on April 27, 1945. Iliac-chip grafts were introduced into the defect on May 11, 1945. The abdominal pedicle was swung, after the scar over the dorsum of the wrist had been completely excised, on June 12, 1945. The last stage of the abdominal pedicle was completed on July 3, 1945, and the wound had healed completely in ten days, terminating three months of mild purulent drainage.

Fig. 11-A: Preoperative lipiodol studies in the anteroposterior and oblique views, made in April 1945.

Fig. 11-B: Postoperative roentgenograms taken on May 30, 1945. The iliac grafts are delineated by arrows.

Fig. 11-C: Postoperative roentgenograms taken on August 15, 1945.

Fig. 11-D: Photograph of the donor and recipient sites in November 1945, prior to free tendon grafts to the extensor tendons of the fingers.

erated by upward displacement of the femoral head. The wound was partially closed, and had healed by second intention within three weeks. Two subsequent flare-ups (with pain and fever, but no discharge) during the third and fifth weeks after operation were controlled with penicillin, which was finally discontinued seven weeks after operation. The patient has been ambulatory in an ischial weight-bearing brace for the past seven months and has had no pain or drainage.

The fourth patient (Case *A*-9) had chronic osteomyelitis of the lateral condyle of the humerus, involving the left elbow joint, secondary to a compound fracture of the humeral condyles, caused by a perforating shell fragment. Most of the joint had become walled off and healing occurred within fifteen days after excision of the infected bone and soft tissue. Three months after operation, the patient had 40 degrees of painless active and passive motion from the right-angle position.

OBLITERATING THE DEFECT BY ILIAC GRAFT

In a large group of cases (31 per cent. in this series), the defect cannot be obliterated by a muscle transplant. The anterior surface of the tibia, the radial styloid, and the calcaneus are covered only by integument, fascia, and ligamentous and tendinous structures, and muscle tissue is not available for a transplant.

FIG. 12-A FIG. 12-B FIG. 12-C

Case *B*-14. A shell fragment perforated the patient's right leg on October 11, 1944, causing a complete paralysis of the peroneal nerve and a compound, comminuted fracture of the tibial and fibular shafts, with resultant chronic osteomyelitis of the tibia and persistent purulent drainage. Excision was performed on March 28, 1945, and a penicillin pack was inserted. The defect was filled with iliac chips on April 18, 1945. Sequestrectomy (a fragment of tibial cortex, not iliac graft) was performed on August 15, 1945. The wound had healed by second intention by October 30, 1945.

Fig. 12-A: Preoperative lipiodol study, made on March 8, 1944.

Fig. 12-B: Anteroposterior and lateral roentgenograms taken on May 10, 1945, three weeks after graft with iliac chips, show the sequestrum, delineated by arrows, and the appearance of the iliac bone filling the defect.

Fig. 12-C: Postoperative roentgenograms taken on September 27, 1945, showing consolidation of iliac grafts.

The tibial defects are usually deep and, after excision, present a rigid-walled cavity, which, by the usual methods, will take months to be filled. The problem was to find some method of filling these deep defects which would allow prompt healing. In seven patients (Cases 36, 37, 38, 39, 40, 41, and 42 of Group *A*) the area of destruction in the tibia was mostly in cortical bone or along the lateral or posterior surface. After excision, the superficial defect was obliterated by closure of the skin and subcutaneous tissues or muscle, depending upon the location of the osteomyelitic focus. There was prompt healing in all.

In June 1944, a large purulent, chronic osteomyelitic focus in the upper tibial area was excised radically. The bone defect was filled loosely with gauze dressings, wrapped around a Dakin tube, through which penicillin solution could be instilled four times daily. On the eighth day the wound was inspected, and it appeared exceptionally clean; the entire bony defect was thinly covered with healthy "velvety-appearing" granulations. If viable (and therefore infection-resistant) tissue could be placed in this defect, it seemed that the prospect of healing would be excellent. The utilization of a pedicle of subcutaneous fat had already proved impractical. To use a pedicle formed from adjacent leg muscles was not feasible, as too often this would cause permanent disability from loss of the physiological function of the sacrificed muscle. Since Abbott showed that a graft of cancellous iliac bone is rapidly revascularized and becomes part of the surrounding bone in a comparatively short interval, it was decided to try this type of graft in filling such defects; meanwhile, systemic penicillin was used to ensure that infection would cause minimum interference with healing. If this procedure proved successful, considerable time would be saved, since further bone-graft operations would be unnecessary. At first, large pieces of ilium, including the iliac cortex, were used, but with indifferent success. In fact, in two of

the first three cases in which this was attempted, suppuration continued. Upon analysis these two failures, it was noted that, when the grafts were disturbed, the cancellous porti would bleed (showing early revascularization), while the cortical portion of the gra showed definite suppuration. It was then decided to use only small cancellous iliac chi (approximately four centimeters long, one centimeter wide, and three millimeters thick from which all cortical bone had been removed. Since this type of graft has been use there has been no deep sequestration or formation of chronic sinus tracts.

The procedure in this second group (Group *B*) is complete excision of all infected a avascular tissue, as in Group *A*. The bone defect is lightly filled with gauze dressing wrapped around either a Dakin tube or male catheter, which extends through the gau dressing and cast. Through this, from two to four cubic centimeters of penicillin solutio containing 250 units per cubic centimeter, are instilled four times during the twenty-fo hours; and 25,000 units are administered intramuscularly every three hours. After fr seven to ten days, depending upon the size of the defect, the wound is inspected; the defe has always been found to be covered with a thin layer of healthy granulations.

The patient is operated upon the next day. The appropriate iliac crest is prepared i the usual manner. Sufficient bone is removed in thin strips, and the cortex is discarde The iliac wound is closed before the recipient site is exposed, in order to prevent any cr contamination. The granulating defect is thoroughly and gently irrigated with from o to two liters of normal saline; and the surrounding skin is prepared with ether, alcoh and merthiolate, care being taken to get none in the recipient site. The grafts are th "shingled" or "bricked" into place so as to fill the defect (Fig. 10). The wound is close except for a small opening or vent directly over the grafts, which is maintained by vaseline-gauze wick; and the part is immobilized in plaster. In this way the entire e tremity is placed at rest, the iliac grafts are immobilized, and provision is made for drai

FIG. 13-A

FIG. 13-B

Case *B*-13. Patient sustained a perforating gunshot wound of the left leg on September 22, 1944, causing a compound, comminuted fracture of the mid-tibial shaft, with resultant chronic osteomyelitis. Excision was performed and a penicillin pack was inserted on May 4, 1945. Iliac chips were placed in the bone defect on May 25, 1945. The surgical wound healed on June 14, 1945, and remained healed, except for serous drainage from a "skinned" area for one week in July 1945.

Fig. 13-A: Preoperative roentgenograms taken on January 13, 1945.

Fig. 13-B: Postoperative roentgenograms taken on September 26, 1945.

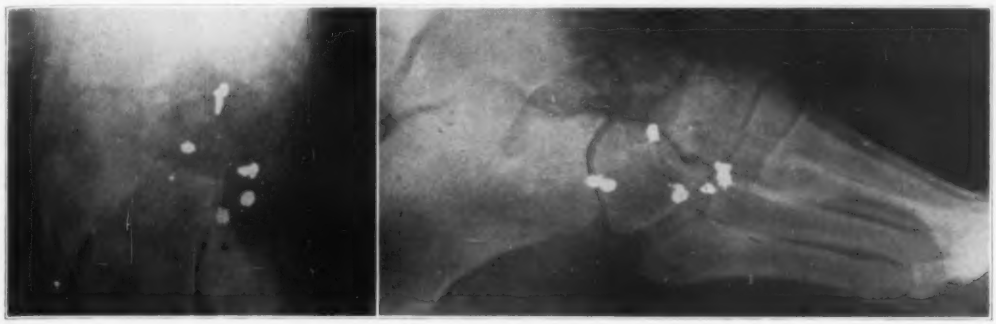

FIG. 14-A

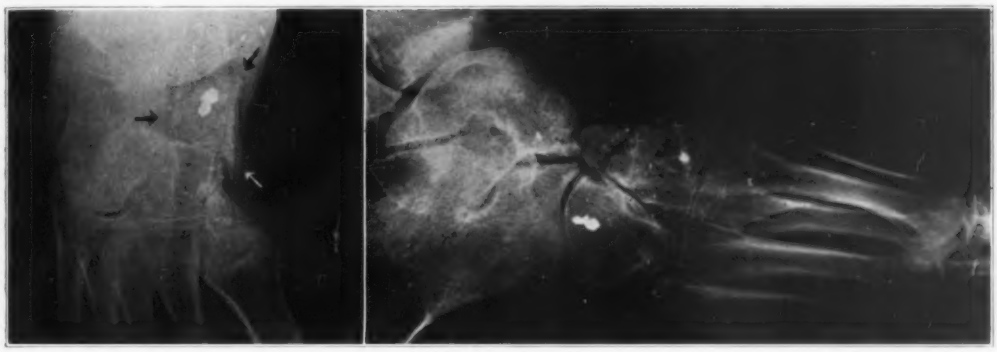

FIG. 14-B

Case *B*-19. Patient sustained a perforating shotgun wound at close range on December 25, 1944, with loss of the neck of the talus and the scaphoid tarsal, and considerable soft-tissue injury. Débridement, with vaseline gauze in wounds and plaster-cast immobilization, was performed the day of injury. Secondary closure was performed on the dorsal wound on February 2, 1945. Iliac chips were placed in the bone defect on February 27. A thin split-thickness skin graft was applied on April 9; it healed in three weeks. The patient has been ambulatory for seven months, with a barely perceptible limp, but with occasional slight, recurrent serous drainage. The sinus was explored and found to be subcutaneous only (not entering the bone-graft area). There has been no drainage since.

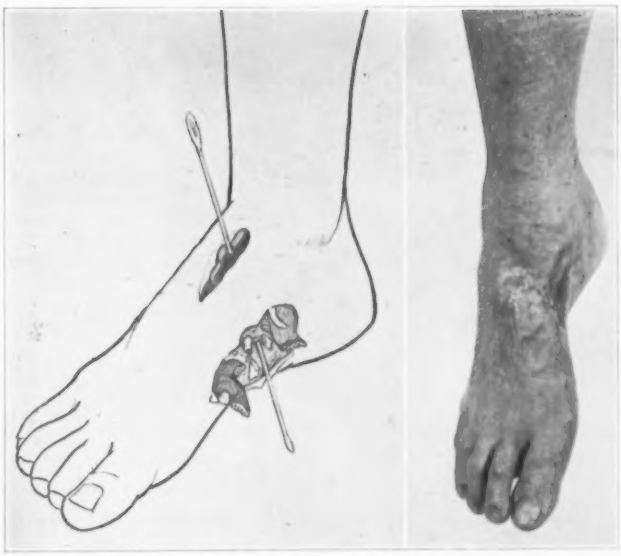

FIG. 14-C FIG. 14-D

Fig. 14-A: Roentgenograms taken on December 25, 1944, the day of injury.

Fig. 14-B: Roentgenograms of August 8, 1945; the iliac grafts, outlined with arrows, have taken on the appearance of a tarsal bone.

Fig. 14-C: Sketch of the injury.

Fig. 14-D: Photograph of the foot in November 1945.

age of exudate into the cast. Twenty-five thousand units of penicillin every three hours is continued intramuscularly for one or two weeks, depending upon the clinical course of the patient.

Several methods of local postoperative care have been tried, but with the one men-

FIG. 15-A

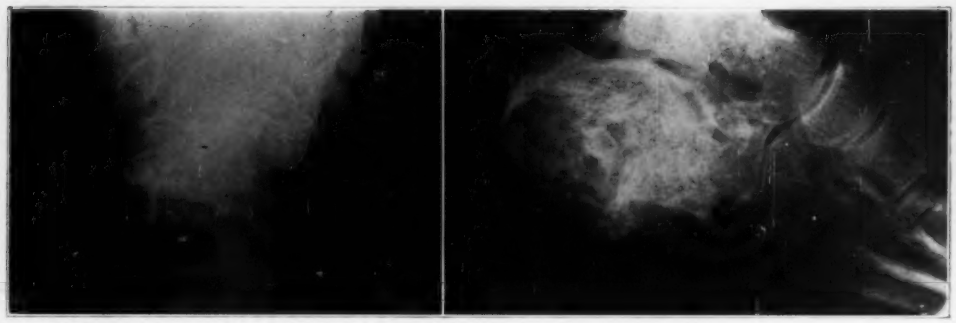

FIG. 15-B

FIG. 15-C

Case *B*-20. Patient sustained a perforating gunshot wound of the right heel on August 28, 1944, causing a compound, comminuted fracture of the right calcaneus, with resultant chronic osteomyelitis. Excision and closure were performed on January 30, 1945, but drainage persisted. Excision was performed and penicillin pack placed in the defect on March 9, 1945. Iliac chips were placed in the defect on March 23, 1945. The wound had healed on April 23, 1945, and the patient has been doing light duty for four months (concluded in October 1945) without complaint. Walking gait shows no limp, but a perceptible limp is present when running.

Fig. 15-A: Preoperative lipiodol study made on December 15, 1944.

Fig. 15-B: Postoperative roentgenograms taken on May 14, 1945.

Fig. 15-C: Photograph of the foot in November 1945.

tioned the wounds have uniformly appeared better. In two early cases, treated without plaster, it was felt that at least a part of the failure was due to pocketing of the exudate, which prevented the granulations from growing up, engulfing the grafts, and incorporating them solidly into the recipient site by organization.

The first cast is changed in three weeks and the wound is inspected. In small defects (two centimeters in diameter) the area will be found to be ready for secondary closure. In one case (Figs. 11-A to 11-D) an abdominal pedicle, previously prepared, was swung into position at this time, with complete and prompt healing. In larger defects the vaseline wick is reinserted and the part is placed in a cast for an additional three weeks, during which time the patient may be up in a wheel chair only. In most instances the wound has healed, at least sufficiently so that closure by simple plastic procedures may be accomplished. Such procedures have included simple wound revision and secondary closure, with

FIG. 16-A

FIG. 16-B

Case *B*-16. A shell fragment penetrated the patient's left leg on February 15, 1945, causing a compound, comminuted fracture of the left lower tibial shaft, with resultant chronic osteomyelitis. Excision was performed and a graft of iliac chips was applied to the defect on August 7, 1945. The wound had healed by second intention on September 15, 1945.

Fig. 16-A: Preoperative lipiodol study made on July 11, 1945.

Fig. 16-B: Postoperative roentgenograms taken on October 10, 1945.

Fig. 16-C: Photograph of the operative site in November 1945. (The patient is in a wheel chair because of a fracture of the right femur and palsy of the peroneal nerve on the right side, sustained in the original injury.)

FIG. 16-C

relaxing incision when necessary, pinch grafts, or a pedicle graft. There are three criteria for timing secondary or plastic closure: first, that no sinus tracts are present; second, that healthy granulations have covered all the graft and the recipient bone; and third, that the surrounding soft tissues are not oedematous or inflamed. If these criteria do not obtain, moist dressings of normal saline are applied every four hours for from two to four days, through a window in the cast. This usually suffices to prepare the area for the procedures mentioned.

In three instances, complete closure over the grafts was done primarily, with an eccentrically placed needle for introduction of the penicillin solution. Results in these cases were good, but it was believed that the benefit was derived from the needle as a drain to relieve the wound of exudate, rather than from any beneficial results from local penicillin. In two cases (*B*-16 and *B*-17)—both defects of the tibial shaft—the excision and graft were accomplished at one operation. Healing occurred in both, although it was delayed by an estimated two to three weeks in each instance.

Twenty cases * of chronic osteomyelitis have been treated by radical excision and a graft of iliac bone. Results were considered good when the wound healed within nine or ten weeks,—usually by second intention or with the aid of skin grafts or plastic revision; and fair when complete healing occurred, which, however, took longer than ten weeks. Failure was classified as persistence of drainage after four months. The results were good in eight cases and fair in eight cases; failure occurred in four cases. Four of the patients rated as having fair results required a single curettage of a persistent sinus, with serous drainage. These patients have been observed for an average of nearly five months since curettage, and no subsequent drainage or inflammation has occurred. One other case rated as a fair result required a sequestrectomy after the iliac-bone graft; healing was then prompt. The sequestrum had inadvertently been overlooked at the time of the first operation, and was apparent in the roentgenograms taken after the iliac graft (Fig. 12-B). This is a reminder that the entire area should be explored thoroughly at the primary operation, and that no overhanging ledges should be left. "Cup-like", rather than "saucer-like", defects have been the aim in excising the deep osteomyelitic foci. If a sinus persists for as long as two weeks after removal of the cast, surgical exploration is indicated. Of the five cases mentioned, prompt healing followed such treatment in all, and the results might have been classed as good if exploration had been done early.

Evaluation of the results shows that the failures were either in cases which had large bone defects (approximately 4 to 4.5 centimeters in diameter) in the upper tibia, or in those in which a large defect in the skin and subcutaneous tissue near the ankle was present. Observation of the cases with bone defects in the tibia indicates that the revascularization of the grafts is fast enough to overcome necrosis only if the diameter of the graft bed is not greater than 2.5 to 3.0 centimeters. In the future, if the diameter is greater than 3.0 centimeters (the length being of little concern), the surface of the bone will be skived down so that the defect does not form such a deep well (Fig. 10, *A*). The two instances rated as failures, in cases with large skin defects and subcutaneous defects in the lower tibia, show good results by roentgenogram, as far as the iliac-bone graft is concerned. Clinically, the wound remains as a shallow granulating area with a mild serous exudate, and no sinuses are present. All that is needed for complete healing is a pedicle graft from the opposite calf, which is now in the process of being prepared. In the future, in this type of case a pedicle graft will be made ready to swing at the end of from three to six weeks after the iliac graft has been accomplished, depending upon the appearance of the wound. This was done in one instance (Case *B*-1). Whatever plastic repair of the skin is necessary should be completed within from six to seven weeks after the iliac graft. All of the grafts, and therefore the bone defect, will be fully organized at that time.

Recently, in two cases of chronic osteomyelitis of the femoral shaft, the deep defects were filled with iliac-bone chips, in order to establish the relative merits of the two methods of obliterating "dead" space in this area. If successful, subsequent bone-grafting would be unnecessary and much time would be saved. In both instances, however, purulent drainage continued and many of the grafts sequestrated, necessitating reoperation for muscle transplant after removal of all grafts. The cause of these two failures is obscure, since the same method has been successful in the tibial shaft; but, as a consequence, the use of iliac-bone chips in any defect that can otherwise be obliterated by muscle tissue is not advocated. These two cases are not included in the statistical analysis, since both were for trial only in an area where muscle transplants had already proved successful.

A method which yields only 40 per cent. of good results is subject to just criticism. It is now clear, however, that, of the four poor results, all were foredoomed to failure, and also that many of the cases in which the results were rated as fair could have been healed

* The twenty-first case so treated (a defect of the tibial shaft) shows a slight serous drainage at the end of the sixth week after operation, and complete healing within the ensuing two weeks is anticipated. However, this case is not included in the statistical analysis.

in a shorter period of time. With the benefit of experience and improvement in technique, the percentage of good results should improve. Certainly with the present bacteriostatic drugs and the prospect of still more effective bacteriostatic, and possibly bactericidal, agents in the near future, the incidence of hematogenous osteomyelitis will be exceedingly small. With good surgical technique and such drugs, bone infection following elective surgery and compound fractures should be negligible. However, in the few instances which will occur, radical surgical excision of all devitalized tissue and immediate grafts of cancellous iliac bone should be effective in a high percentage of cases.

SUMMARY

1. The prompt and permanent healing of chronic pyogenic osteomyelitis is imperative, in order to prevent the many serious complications and sequelae and to permit early reconstructive surgery, when necessary.

2. With the present-day bacteriostatic drugs, more radical surgery can be accomplished without danger to life or limb.

3. Sixty-four separate foci of chronic osteomyelitis in sixty-one male patients, between eighteen and thirty-seven years of age, have been treated during the past sixteen months.

4. Early healing (within ten weeks) occurred in 78.1 per cent. Including the eight cases in the iliac-graft series, in which healing was delayed over the ten-week period, and the one case in which re-excision was necessitated by a secondary sequestration, complete healing occurred in 93.7 per cent.

5. The method used and advocated is founded upon the principle of complete excision of an infected and avascular tissue, obliteration of the "dead" space, and wound closure. Wherever possible, obliterating the dead space with viable muscle has been the method of choice, since 97.7 per cent. of the wounds in this group healed promptly. Bone-grafting should be done later, if necessary, to reinforce any bone weakness. In the calcaneus, the anterior surface of the tibia, and the radial styloid, obliterating the dead space with grafts of cancellous iliac bone has shown definite merit and has been time saving.

REFERENCES

ABBOTT, L. C.: The Use of Iliac Bone in the Treatment of Ununited Fractures. *In* Lectures on Reconstruction Surgery, Am. Acad. Orthop. Surgeons, pp. 13–22. Ann Arbor, Michigan, Edwards Bros. Inc., 1944.

MERCER, WALTER: Orthopaedic Surgery, Ed. 3. Baltimore, Williams and Wilkins Co., 1944.

STARR, C. L.: Acute Hematogenous Osteomyelitis. Arch. Surg., **4**: 567–587, 1922.

METATARSAL FRACTURES

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Foot trauma, both in industry and in the Armed Forces, is probably one of the most frequent contributors to the loss of vitally needed man-hours. To rehabilitate the injured man as rapidly as possible, without in any way jeopardizing his physical well-being, presents a major problem, the answer to which would seem to lie in a method of treatment which would minimize the period of disability and discomfort, yet produce the desired end result. Experience with the treatment of fractured metatarsals over a three-year period leads the author to believe that the type of treatment described herein has proved its value and efficacy in terms of the short period of disablement experienced and the excellent end results obtained.

REVIEW OF CURRENT METHODS OF TREATMENT

Up to the present time, the accepted treatment for fractured metatarsals has been rigid immobilization by means of a plaster cast, extending from the toes to the tibial tubercle, care being taken to mold the longitudinal and transverse arches of the foot. In only a few instances has any other form of treatment been advocated. For example, Christopher recommends the Davis splint, which consists of a flexed wooden splint applied to the sole of the foot in an attempt to maintain the longitudinal and transverse arches. However, in the use of this splint, weight-bearing is not allowed for from four to six weeks. Gebhard suggests a Jones bar under the shoe, with weight-bearing in one week; and Berkman uses the regulation army shoe as a splint, without orthopaedic modification. In the last two instances, however, the patient receives support only while actually wearing the shoe, and he is limited to the use of one particular shoe until the fracture has healed. Sirbu and Palmer, in their treatment of march fracture, use the metatarsal pad and strapping, plus a metatarsal bar; the period of non-weight-bearing is twenty-one days, during which time no work is performed.

TREATMENT USED IN CASES STUDIED

The treatment used in this study was the application to the foot of a simple molded leather arch, with or without a metatarsal pad of sponge rubber. The leather arches were of a stock variety, and were applied to the foot by means of adhesive strapping. In the first half of the study a long anterior stirrup of adhesive strapping was used to immobilize the foot and ankle, and to hold the leather arch firmly to the foot. This strapping extended to the tibial tubercle, holding the foot in neutral position as regards eversion and inversion,

FIG. 1-A

FIG. 1-B

FIG. 1-C

Show leather arch applied to foot and held in position by adhesive strapping.

TABLE I

FRACTURES OF METATARSALS IN SIXTY-ONE CASES

Number of Metatarsals Fractured	Bones Involved	Number of Cases	Total
1	First metatarsal	16	
1	Second metatarsal	9	
1	Third metatarsal	7	
1	Fourth metatarsal	2	
1	Fifth metatarsal	8	42
2	First and second metatarsals	2	
2	First and third metatarsals	1	
2	Second and third metatarsals	3	
2	Third and fourth metatarsals	3	
2	Third and fifth metatarsals	1	
2	Fourth and fifth metatarsals	1	11
3	First, second, and third metatarsals	5	
4	First, second, third, and fourth metatarsals	1	
4	Second, third, fourth, and fifth metatarsals	1	
3	Third, fourth, and fifth metatarsals	1	8
Total			61

and in 90 degrees of dorsiflexion. The arch support was held firmly to the fore part of the foot by means of a strapping, similar to that used for an anterior metatarsal arch.

As the study progressed, it was found that the long stirrup was not necessary, and short strips of adhesive tape were used to approximate the leather arch to the foot. These strips did not extend above the malleoli, and thus allowed complete range of motion of the ankle joint (Figs. 1-A, 1-B, and 1-C).

Before the adhesive strapping was applied, the leg and foot were carefully cleansed and shaved, and three coats of tincture of benzoin were applied. It was found necessary to change the strapping about once a week for an average period of four weeks. Under this procedure the skin withstood the strapping with very little difficulty, and in only one case was any serious skin infection encountered. At the end of about four weeks the strapping was removed, and the adhesive tape was trimmed away from the leather arch support. The same arch support was then used in the patient's shoe for an additional period of one month. No massage, baking, or physiotherapy was used after the removal of the strapping.

In the cases in which there was marked swelling, with or without abrasions and lacerations of the skin, the leather arch was held in place by means of an elastic bandage; and physiotherapy in the form of whirlpool treatment was used until the swelling had subsided and the skin had resumed the texture which would permit adhesive strapping to be applied over tincture of benzoin. Approximately 25 per cent. of the cases were treated in this manner.

TABLE II

RESUMPTION OF WEIGHT-BEARING AFTER INJURY

Weight-Bearing Begun	Number of Cases	Per Cent.
Immediately	35	57.4
One to five days after injury	7	11.5
Six to ten days after injury	6	9.8
Over eleven days after injury *	13	21.3
Totals	61	100.0

* This group includes cases of severe contusion of the skin, flare-up of athlete's foot with cellulitis, and fractures with marked displacement. An average of fourteen days were required before active unaided weight-bearing could be resumed.

TABLE III

INTERVAL BETWEEN INJURY AND RETURN TO REGULAR EMPLOYMENT

Time After Injury (*Days*)	Number of Cases
0	7
1 to 10	6
11 to 20	6
21 to 30	17
31 to 40	14
41 to 50	8
51 to 60	3
Total	61

SELECTION OF CASES

During the period from April 1941 to March 1944, ninety-eight cases of metatarsal fracture were seen. Ninety of these cases were treated in the manner described. Of the ninety-eight cases, thirty-seven were not included in this study for the following reasons:

1. Severity of the injury necessitated hospitalization in eleven cases. These included compound fractures and crushing injuries, which produced deep lacerations, with grossly contaminated wounds.

2. Additional fractures of the tarsal bones, tibiae, and fibulae were present in three cases.

3. The check at the end of six months revealed that twenty-three of these men were serving in the Armed Forces. This fact presupposes that they had satisfactory end results. Their absence from our physical and roentgenographic check-ups made it necessary to exclude this group.

The remaining sixty-one cases were used in this study, and included all types of fracture,—from simple fractures without displacement to displaced fractures with only 50 per cent. apposition; many comminuted fractures were present.

FIG. 2-A

FIG. 2-B

J. K., aged forty-eight, received a comminuted fracture of the shaft of the first metatarsal of the left foot on May 21, 1941. He was released for special work the day of the injury; on June 20 he returned to his regular work. The end results were $A_4E_4F_4$; there were no complications.

Fig. 2-A: Roentgenograms taken on the day of injury.

Fig. 2-B: Views of the foot taken on January 5, 1943.

FIG. 3-A

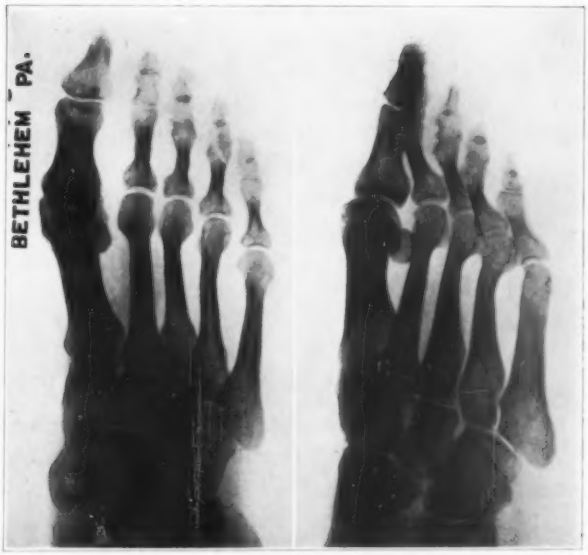

FIG. 3-B

On February 26, 1942, B. B., aged forty-nine, fractured the distal third of the third, fourth, and fifth metatarsals of his right foot, with marked hematoma. He was released for special work the same day, and returned to his regular work on April 14. The end results were $A_4E_4F_4$; there were no complications.

Fig. 3-A: Shows the appearance of the foot on February 26, 1942.

Fig. 3-B: Roentgenograms taken on January 12, 1943.

ETIOLOGY

All of these fractures occurred as the result of direct trauma, such as a heavy object falling on the foot, or the foot being wedged in a moving machine. All the patients were men, from twenty to sixty-one years of age; and they were employed in varying types of jobs, including unskilled laborers, skilled mechanics, riggers, railroad brakemen, and office workers.

FIG. 4-A

FIG. 4-B

F. T., aged twenty-four, received a transverse fracture of the distal third of the first, second, and third metatarsals of his right foot on September 13, 1942. Three days later the patient was released for special work; he returned to his regular work on October 16. The end results were $A_4E_4F_4$; there were no complications.

Fig. 4-A: Roentgenograms taken on September 16, 1942.

Fig. 4-B: Showing end results.

FRACTURE SITE

In the study of sixty-one cases, forty-two cases involved the fracture of only one metatarsal, eleven involved two metatarsals, and eight involved three or more metatarsals. Table I illustrates the metatarsals involved.

WEIGHT-BEARING

Active weight-bearing was started immediately in more than one-half of the cases; in the remaining cases it was started within a comparatively short time after injury (Table II).

RETURN TO WORK

All men were kept on the job, doing either their regular work or selected work. Of the sixty-one patients, none remained away from some type of work for more than four days after injury. Table III shows the interim between the time of injury and the return to *regular* work. In this interim period, however, the men were not idle, but were employed at a selected type of work which, in the author's opinion, hastened their rehabilitation. The majority of men returned to regular work in less than forty days, and by the end of sixty days all had resumed their regular jobs.

In an effort to determine what conditions were conducive to an early return to work, the following factors were reviewed in these cases:

1. Type of injury to soft tissue (contusion, laceration, or maceration).
2. Type of fracture (from simple transverse fracture of one metatarsal, with no displacement, to complicated comminuted fractures of many metatarsals; there were also two compound fractures).
3. Age of the individual in respect to the reparative healing power of the bone.
4. Type of work performed (office work; skilled light work, as by an operator of a machine or lathe, or a craneman; arduous skilled work, such as by a repairman or rigger; and heavy labor, such as that performed with a pick and shovel).

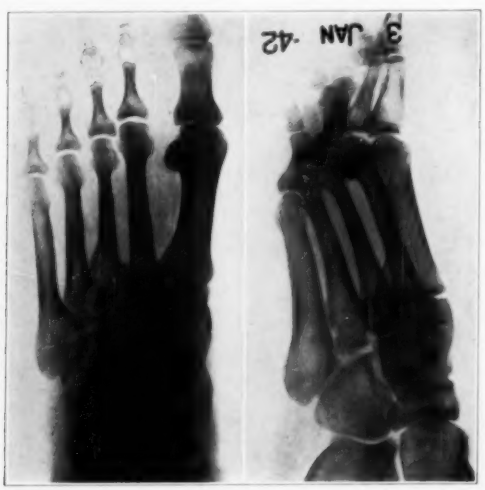

FIG. 5-A

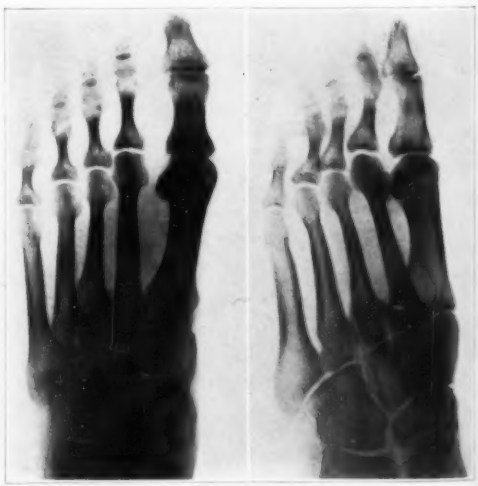

FIG. 5-B

E. E., aged twenty-six, fractured the base of the third and fourth metatarsals of his left foot on January 3, 1942 (Fig. 5-A). He was released for special work the same day, and returned to his regular employment on March 19. The final rating was $A_3E_4F_4$. This man returned to his regular job with no loss of earnings and no symptoms. He was given a rating of A_3 because of widening at the base of the third metatarsal, as shown by roentgenogram on January 12, 1943 (Fig. 5-B).

FIG. 6-A

FIG. 6-B

FIG. 6-C

On September 29, 1942, H. L., aged forty-six, sustained a comminuted fracture of the distal third of the first metatarsal of the right foot. He was released for special work on the day of injury, and returned to his regular work on December 9, 1942, with no symptoms. The end results were $A_3E_4F_4$. The A_3 rating was given because of thickening and shortening of the shaft of the first metatarsal, and distortion of the metatarsophalangeal joint.

Fig. 6-A: Roentgenograms taken September 29, 1942.

Figs. 6-B and 6-C: Follow-up roentgenograms taken on January 11, 1943 (Fig. 6-B) and May 11, 1944 (Fig. 6-C)

Immediate Return to Regular Work

The seven patients who returned to work immediately had only contusions of the soft tissues of the feet. Their fractures were simple, with very little displacement, and in each case only one metatarsal was fractured. Their ages ranged from twenty-seven to fifty-two years. Two were office workers, two were engaged in light labor, and three in skilled labor.

Ten Days or Less

The six patients returning to work within ten days had mild damage to the soft parts. In three cases the fractures were simple; in the remaining three they were comminuted. In one of the cases of simple fracture, two metatarsals were involved. The ages varied from twenty-four to sixty-one years. In regard to occupation, two were engaged in heavy manual labor, one in light work, and the remaining three in skilled heavy work.

Eleven to Twenty Days

Of the six patients who returned to work in from eleven to twenty days, five had simple fractures involving one metatarsal, and the other patient had fractures involving two metatarsals. Two of the five single fractures were displaced. The soft tissue was in good condition in all cases. The patients' ages varied from twenty-four to fifty-five years. Two were engaged in heavy labor and four in skilled work.

Twenty-One to Thirty Days

The fractures in this group of seventeen cases varied from simple transverse fracture of one metatarsal (one case), two metatarsals (five cases), or three metatarsals (one case) to oblique fractures in six cases and comminuted fractures in four cases. Injuries to the soft parts varied from contusions (eight cases) and moderately swollen ecchymotic feet (four cases) to severe damage (five cases). All of the men were engaged in skilled work except four who were employed in heavy manual labor; their ages ranged from twenty-four to fifty-five years, with an average of thirty-two years.

FIG. 7-A

FIG. 7-B

L. D., aged twenty-eight, sustained an oblique fracture of the distal end of the fifth metatarsal of his left foot on June 24, 1943 (Fig. 7-A). He was released for special work two days later, and resumed his regular work on July 20, with no symptoms. The end results were $A_2E_4F_4$. The rating of A_2 was given because of widening of the shaft of the fifth metatarsal, as shown in Fig. 7-B (May 2, 1944).

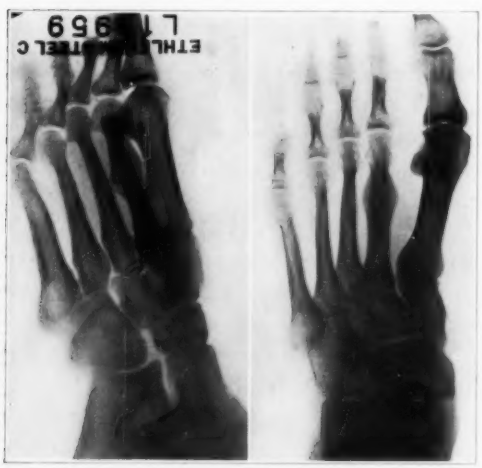

FIG. 8-A

FIG. 8-B

L. B., aged thirty-two, fractured the second metatarsal of his left foot on March 3, 1944. He returned to his regular work the same day. The final rating was $A_2E_4F_4$. The rating of A_2 was given because 25 degrees of angulation was seen in the anteroposterior roentgenograms taken on June 15, 1944 (Fig. 8-A) and May 15, 1946 (Fig. 8-B).

TABLE IV

ANATOMICAL, ECONOMIC, AND FUNCTIONAL EVALUATION OF RESULTS IN SIXTY-ONE PATIENTS

Rating	Number of Cases	Per Cent.
$A_4E_4F_4$	57	93.5
$A_3E_4F_4$	4	6.5
Totals	61	100.0

Thirty-One to Forty Days

Of the fourteen fractures in this group, seven were fractures of a single metatarsal. Five of these had the following complications: arthritis involving the proximal joint, ankle sprain, impaction with 50 per cent. apposition, and a compound fracture. Six cases involved two metatarsals, and in the remaining case three metatarsals were involved. The soft parts were in good condition in two cases, six had mild involvement, and the remaining six had severe involvement. Four of the men were engaged in heavy manual labor, nine in skilled labor, and one in light routine labor. Their ages varied from twenty to fifty-eight years.

Forty-One to Fifty Days

In all but one of the eight fractures in this group, either multiple metatarsals were involved or there were complicated fractures to a single metatarsal. The complications were arthritis, which flared up, and severe injuries to the soft parts. In four cases only one metatarsal was involved; two patients had involvement of two metatarsals, and two had involvement of three metatarsals. The soft parts were in good condition in two cases; in two they were mildly impaired; and in the remaining four they were severely impaired. As in the previous group, four patients did heavy manual labor; the other four were skilled laborers.

Fifty-One to Sixty Days

The three fractures in this group were as follows: The first patient had impacted fractures of the necks of four metatarsals (the second, third, fourth, and fifth), with severe soft-tissue damage. The second patient had a fracture of the middle third of the second metatarsal, with severe soft-tissue damage. The third case was one of transverse fracture of the proximal third of the fifth metatarsal, with slight soft-tissue damage.

From the foregoing data, the following deductions can be drawn:

1. The age of the patient played no part in the individual's early return to work. In the range from twenty to sixty-one years, there seemed to be no marked difference in rapidity or amount of bone repair.

2. Except for two office workers, the man's occupation did not markedly affect his early return to work.

3. Condition of the soft parts and multiplicity of the metatarsals involved had the most direct effect on prolongation of the length of time spent by an individual on selected work.

FOLLOW-UP STUDY AND END RESULTS

Follow-up roentgenograms were taken six months after injury.

Final evaluation of the efficacy of this treatment, made from an anatomical, economic, and functional standpoint, showed excellent end results (Table IV). The method of rating is that used by the staff of the Fracture Service of the Massachusetts General Hospital [5].

Rating in each case is based upon three factors,—the anatomical (A), the economic (E), and the functional (F). The numbers used after each letter range from four to zero, inclusive. Four denotes an end result of from 87.5 per cent. to 100 per cent.; three from 62.5 per cent. to 87.5 per cent.; two from 37.5 per cent. to 62.5 per cent.; one from 12.5 per

cent. to 37.5 per cent.; and zero anything below 12.5 per cent. The highest possible rating is thus $A_4E_4F_4$.

The anatomical result was determined by the alignment and apposition of the fragments, as revealed by roentgenograms; the functional result by examination of the range of motion in the articulations adjacent to the fracture, the muscle power, and freedom from pain, including symptomatology of the longitudinal and transverse arches; and the economic result by the patient's earning power,—whether he was able to return to his former job or to earn as much as he had previously.

SUMMARY

It is felt that the application of this simple treatment accelerated the return of men to active work and reduced to a minimum the days lost. Had the accepted plaster-of-Paris method of treatment been used in these cases, the average period of disability would have been six weeks, with a probable total loss of 2,772 man-days, as compared with the 132 days lost in this series. In addition, the psychological effect of not having to wear a cast helped the injured man to justly minimize his injury and encouraged him to use his injured foot more freely, thus maintaining good circulation and hastening bone repair.

REFERENCES

1. Berkman, E.: Etiological Possibilities of March Fractures. J. Bone and Joint Surg., **25**: 206–207, Jan. 1943.
2. Christopher, Frederick: Minor Surgery, Ed. 4, p. 754. Philadelphia, W. B. Saunders Co., 1940.
3. Gebhard, U. E.: Simple Treatment for Fractured Metatarsals. Industrial Med., **11**: 157, 1942.
4. Sirbu, A. B., and Palmer, A. M.: March Fracture. A Report of Fifteen Cases. California and Western Med., **57**: 123–127, 1942.
5. Wilson, P. D., Ed.: Experience in the Management of Fractures and Dislocations. (Based on an Analysis of 4390 Cases.) Philadelphia, J. B. Lippincott Co., 1938.

ARTHROPLASTY OF THE TEMPOROMANDIBULAR JOINT IN CHILDREN WITH INTERPOSITION OF TANTALUM FOIL

A Preliminary Report

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Ankylosis frequently recurs after arthroplasty of the temporomandibular joint in children, and this has always been disappointing. In performing the arthroplasty by the accepted methods, fascia has been the usual intervening material inserted to secure a false

FIG. 1-A

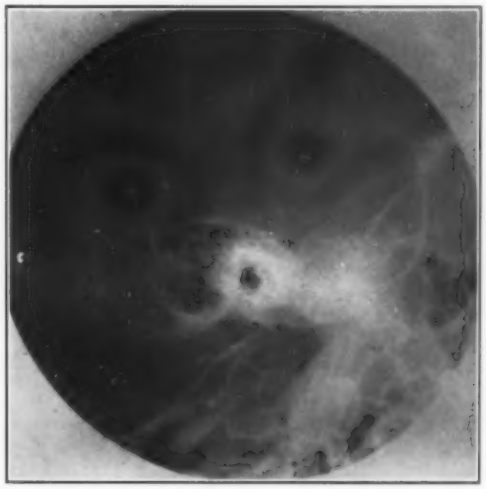

FIG. 1-B

Fig. 1-A: Normal left temporomandibular joint.
Fig. 1-B: Ankylosed right temporomandibular joint, before operation.

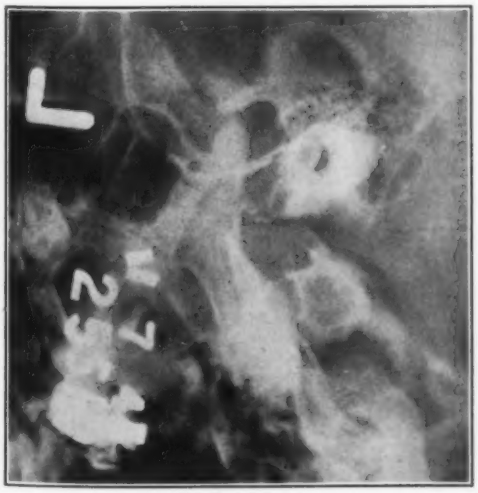

FIG. 2-A

FIG. 2-B

Fig. 2-A: Normal left temporomandibular joint.
Fig. 2-B: Right temporomandibular joint, with tantalum foil in position.

FIG. 3
Postoperative roentgenogram of arthroplasty.

FIG. 4
Mandibular excursion, one year after operation.

FIG. 5-A

FIG. 5-B

Result one month after operation.

FIG. 6-A

FIG. 6-B

Functional result, thirteen months after operation.

joint. The technique of arthroplasty of the mandible will not be considered in this discussion, but rather the prevention of recurrence of the ankylosis.

A study of the recurrent case usually reveals bridges of bone from the mandible to the base of the skull, and, although the line of the false joint is evident, a firm union is slowly being created. The osteogenetic activity which occurs in these children is unfortu-

nate. In many cases the fusion is so extensive, in proportion to the size of the mandible and the age of the child, that the surgeon has a real problem to cover the denuded bone surfaces, after the ankylosis has been relieved. Mandibular pressure on the joint is very great in children, and probably is a factor in destroying the intervening fascia.

To overcome this fascial disappearance, it was decided to use a more lasting material, and tantalum was selected. The thin foil is cut considerably larger than the denuded bone surface, folded, and placed over the exposed bone surfaces. One piece is placed over the base of the skull and a second piece, similarly cut and folded, is placed over the mandibular portion, particularly down the medial side. Thus there are four layers of tantalum foil between the bone surfaces. It is a bit brittle and cracks, but satisfactory coverage can be secured and even small pieces can be packed in areas where intervening material is desired. It cannot be fastened with sutures, but the mandibular pressure packs the tantalum foil firmly against the denuded bone and creates an area which discourages osteogenesis and the recurrence of ankylosis.

CASE REPORT

C.L.C., a four-year-old white girl, was first examined in December 1944. The history revealed that in 1940 the patient had had acute mastoiditis of the right side, for which a radical mastoidectomy had been performed. She had had a rather stormy course, and about forty days after operation she began to have difficulty opening her mouth. This became so severe that a local physician gave the child a general anaesthetic and opened the mouth forcibly. In a short time, however, she again could not open her mouth, and the right cheek became more prominent than the left. During the past several years, the mouth had been opened forcibly about twenty times. At the time of examination, the patient was unable to open her mouth.

A roentgenographic study disclosed extensive ankylosis of the right temporomandibular joint (Fig. 1-B). The left temporomandibular joint was normal (Fig. 1-A).

On January 6, 1945, an arthroplasty of the right mandible was performed; tantalum foil was used as the intervening material between the denuded bone ends (Figs. 2-B and 3). Four weeks later the function of the jaw was satisfactory (Figs. 5-A and 5-B).

Roentgenograms taken a year later show satisfactory excursion of the patient's mandible (Fig. 4). Photographs taken thirteen months after operation show the functional result of the arthroplasty (Figs. 6-A and 6-B). There was no evidence of increasing rigidity of the mandible to indicate future restriction of motion.

GUNSHOT WOUNDS OF THE MAJOR JOINTS

BY CAPTAIN PAUL W. CARNEY, CAPTAIN WILLIAM T. FITTS, JR., AND CAPTAIN CHARLES K. KIRBY

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Among the most serious of all war injuries of the extremities are gunshot wounds of the major joints. Treatment of these injuries is usually difficult and the results are often disappointing. Disability of some degree—due to chronic arthritis, instability, fibrous or bony ankylosis, and associated nerve injuries—occurs in a high percentage. Septic arthritis, which is a frequent complication, often endangers life.

Concerning the treatment of joint wounds, there is notable difference of opinion, probably because the results following any method of treatment are so often discouraging. Fruchaud has stated that many French surgeons favor leaving the joint widely open at the primary operation, while the British usually prefer closure of the capsule whenever possible. During a visit to Russian hospitals, Watson-Jones found that the Russians have advocated early, complete excision of acutely infected knee and hip joints in preference to arthrotomy. Sir Anthony Bowlby, after a wide experience with joint injuries, advised amputation for comminuted fractures of the femoral condyles with involvement of the knee joint; this suggestion would probably be accepted by few American surgeons.

During World War II, the authors have seen very few reports by American military surgeons of gunshot wounds of the joints. Experience with these injuries at a General Hospital in India during the North Burma Campaign has been reviewed. In caring for a large number of Chinese patients, whose treatment was necessarily carried to completion before discharge in most instances, it has been possible to observe all phases of treatment, including the late reconstructive stages of arthroplasty and arthrodesis.

ANALYSIS OF CASES

This series comprises 134 wounds of the major joints in 133 patients. Table I gives their distribution. Wounds of the knee joint were the most frequent, constituting 57 per cent. of the total. The injuries were equally distributed as to the side of the body, with the exception of shoulder and hip wounds, in which the right shoulder and the left hip predominated.

TABLE I

DISTRIBUTION OF 134 INJURIES OF MAJOR JOINTS

Joint	Right	Left	Total	Per Cent. of Total
Hip	3	8	11	8.2
Knee	38	39	77	57.5
Ankle	6	7	13	9.7
Shoulder	10	2	12	8.9
Elbow	10	11	21	15.7
Totals	67	67	134	100.0

Eighty-six per cent. of the wounds were in Chinese soldiers, and 14 per cent. in American soldiers. Since almost all of the Chinese patients were kept in this Hospital during the entire course of treatment, the final results are known in most instances. Several American patients were evacuated to the Zone of the Interior before the outcome could be ascertained.

The North Burma Campaign has been called a "small-arms" war. Almost half of the wounds were caused by bullets of twenty-five caliber, and the remainder by shell fragments,—usually mortar. Undoubtedly the wounds were less severe than those in theaters

TABLE II

SUMMARY OF DEFINITIVE TREATMENT

Treatment	Hip	Knee	Ankle	Shoulder	Elbow	Total	Per Cent. of Total
Immobilization							
Plaster	9	71	13	12	21	126	94.0
Traction	2	6	0	0	0	8	6.0
Local Medication							
Sulfanilamide	All	All	All	All	All	134	100.0
Chlorazene	5	12	1	1	1	20	15.0
Penicillin	5	5	1	1	1	13	9.7
General Medication							
Sulfonamides	All	All	All	All	All	134	100.0
Penicillin	7	11	1	1	4	24	18.0
Transfusions of whole blood	10	19	2	0	2	33	24.6
Plasma transfusions	4	1	0	0	1	6	4.5
Operative Procedures							
Secondary débridement	0	2	2	0	2	6	4.5
Removal of foreign bodies	2	10	1	1	2	16	12.0
Aspiration	0	15	0	0	0	15	11.2
Incision and drainage	9	20	4	2	2	37	27.6
Amputation	0	1	0	0	0	1	0.7
Early joint resection	0	3	0	0	0	3	2.2
Manipulation under anaesthesia	1	3	0	2	2	8	5.9
Late operative fusion	0	5	0	4	3	12	8.9
Arthroplasty	1	0	0	0	0	1	0.7

of operation where more destructive missiles prevailed. Fifty-four per cent. of the wounds were penetrating and 46 per cent. were perforating.

Fracture of adjacent bone complicated the joint wound in 75 per cent. of the cases. In the remaining 25 per cent. (twenty-seven wounds of the knee and seven of the elbow), there was no associated fracture.

In fourteen instances (10.4 per cent.) there was an associated nerve injury, with the following distribution:

Shoulder	
Axillary nerve	1
Elbow	
Radial nerve	3
Ulnar nerve	3
Median nerve	1
Hip	
Sciatic nerve	4
Knee	
Peroneal nerve	2

Débridement was carried out in portable surgical hospitals in 96 per cent. of the patients. The adequacy of the débridement varied considerably. In approximately one third there was a record of closure of the capsule; in many the capsule could not be closed because of the extent of the wound. Following débridement, sulfanilamide was applied locally to every wound. In only one instance was the skin closed primarily; in the remainder the wound superficial to the capsule was held open with vaseline gauze. Prophylactic sulfonamide therapy was begun orally soon after injury, for penicillin was not available at any time during this Campaign in the forward installations. Circular plaster was used to immobilize the joint during evacuation in almost every instance.

The average interval before admission to this Hospital after being wounded (following

TABLE III

COMPLICATIONS OBSERVED IN 90 OF THE 134 JOINT WOUNDS

Complication	Hip	Knee	Ankle	Shoulder	Elbow	Total	Per Cent. of Total Wounds
Septic arthritis	9	20	7	4	5	45	33.6
Osteomyelitis	8	11	5	4	1	29	21.6
Soft-tissue abscess	2	4	0	0	0	6	4.5
Anaerobic cellulitis	0	2	0	0	2	4	3.0
Septicaemia	0	1	0	0	0	1	0.7
Secondary hemorrhage	1	0	0	0	0	1	0.7
Thrombophlebitis	2	0	0	0	0	2	1.5
Volkmann's contracture	0	0	0	0	1	1	0.7
Sudeck's atrophy	0	0	1	0	0	1	0.7
Totals	22	38	13	8	9	90	67.0

a litter haul of varying distances and evacuation by air for more than 100 miles) was six days, although half of the patients were admitted within the first two days.

Treatment at this Hospital is summarized in Table II. The "closed-plaster" technique was used for the definitive treatment of more than 90 per cent. of the wounds. Continuous traction (balanced skeletal traction-suspension, with a Kirschner wire for transfixion) was used in only eight instances: two wounds of the hip and six of the knee. In all instances in which traction was used, there was an associated fracture, and traction was used primarily for treatment of the fracture.

Local and oral sulfonamides were used prophylactically in all patients. Penicillin was available only during the latter part of the Campaign, and then in very limited amounts. Of the twenty-four patients who received penicillin, it was used prophylactically in only two. Several chronically infected joints containing considerable necrotic material were irrigated at frequent intervals with a 1 per cent. solution of chlorazene. Anaemia and hypoproteinaemia were corrected as early as possible by transfusions of whole blood and plasma and by dietary measures.

An inadequate primary operation necessitated the secondary débridement of six wounds. Foreign bodies were present in sixteen joints on admission, and were removed as soon as practicable. Septic arthritis required incision and drainage in thirty-seven patients. There was only one amputation; this was performed because of gas gangrene following an injury to the knee joint. Three chronically infected knee joints were resected.

Complications and their incidence are shown in Table III; they occurred in ninety of the 134 joint wounds. Septic arthritis was the most frequent (33.6 per cent.) and the most serious complication. Osteomyelitis was two thirds as frequent, occurring in 21.6 per cent. of all the wounds (27 per cent. of the cases associated with a fracture). In one patient septicaemia developed, in spite of the prophylactic use of sulfonamides and penicillin. In this case the causative organism, *Bacillus pyocyaneus*, was resistant to sulfonamides and penicillin.

Anaerobic cellulitis without gangrene developed in four wounds, and was controlled by prompt surgery. There was only one instance of gas gangrene, and this necessitated amputation. The Volkmann's contracture was due to ischaemia, caused by constriction at the elbow by a tight, unsplit, unpadded plaster cast, used during evacuation.

There were three deaths in the series,—a mortality of 2.3 per cent. One was due to pulmonary embolism following incision and drainage of a hip joint for septic arthritis; an associated peritonitis caused the second; and the third was due to *Bacillus pyocyaneus* septicaemia, following a knee-joint wound with no associated injuries.

At present, 118 joints have been observed for a sufficiently long period to permit classification of the results, as shown in Table IV. In all likelihood, several of the joints with motion of less than 50 per cent. of normal at present will show further gradual improve-

ment, and may in time regain nearly normal function. Also, in some of the joints which now have fibrous ankylosis, bony ankylosis will eventually develop.

PRIMARY TREATMENT

Because of the vulnerability to infection of the synovial membrane and the articular cartilage, and the inevitable progressive damage caused by retained foreign bodies and unattached bone fragments, a thorough and painstaking primary débridement of joint wounds is imperative for good results. Emphasis must be placed primarily on the prevention of infection, for once infection has become established in a joint, its treatment is extremely difficult. If an early operation has not been possible, a delay of from one to several days is not a contra-indication to débridement, even in the presence of infection. In such instances the authors have been impressed with the value of excising devitalized tissue and removing foreign bodies in improving the chances for a good result.

If there is any doubt about the adequacy of the débridement or the removal of all foreign bodies, the capsule should not be closed. Suture of the capsule in the presence of devitalized tissue or foreign bodies may prove disastrous. If a thorough débridement is assured, closure of the capsule is advisable and is of value in the prevention of infection. In this series it has not seemed valid to compare the incidence of infection in joints with and without closure of the capsule, because in most instances in which the capsule was not sutured, the extent of the wound precluded closure. Such wounds were the most severe, with extensive damage to soft tissue and bone, and thus more likely to become infected. If the capsule cannot be closed, the joint should be carefuly protected from further infection by an occlusive dressing. Under no circumstances should gauze, rubber dam, rubber tubes, or other drainage material be placed within the joint cavity.

Since local and oral sulfonamides were used in the treatment of all of these wounds, it is difficult to appraise their value in the prevention of infection. It seems likely, however, that they have been responsible for the prevention of spreading infection and septicaemia in many instances. In the one case of septicaemia in our series, the causative organism, *Bacillus pyocyaneus,* was sulfonamide-resistant. Since penicillin has been shown to be active in the presence of blood, pus, and tissue autolysates, it should prove to be of much greater value than the sulfonamides in the treatment of joint injuries. Local and general penicillin therapy should be instituted as soon as possible after the patient has been wounded.

TABLE IV

FUNCTIONAL RESULTS IN 118 JOINT WOUNDS

Result	Hip		Knee		Ankle		Shoulder		Elbow		Total	Per Cent of Total
	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)		
More than 50 per cent. motion	1	16.6	45	62.5	2	18.1	2	18.1	8	44.4	58	49.2
Less than 50 per cent. motion	0	0	10	13.9	3	27.3	6	54.7	4*	22.2	23	19.5
Fibrous ankylosis	0	0	8	11.1	3	27.3	2	18.1	3	16.7	16	13.5
Bony ankylosis	5	83.4	9	12.5	3	27.3	1	9.1	3	16.7	21	17.8
Totals	6	100.0	72	100.0	11	100.0	11	100.0	18	100.0	118	100.0

TREATMENT AT FIXED INSTALLATIONS

A. *General Treatment*

Almost all of these wounds were treated by the closed-plaster technique, which allowed the wound to heal by second intention. In more recent injuries, not included in this series, clean joint wounds have been closed between the fourth and tenth day after injury, as suggested by Churchill. It is especially important that joint surfaces be covered as soon as possible, by the apposition of overlying soft tissue. When there has been considerable loss of skin, the wounds should be dressed early with split-skin grafts.

The involved joints should almost always be immobilized in the position of election for fusion, unless treatment of an associated fracture requires another position. Even then, if infection is present, the position of election should be used in order to avoid ankylosis at an unfavorable angle.

The early use of massive transfusions of whole blood has appeared to be of value in the prevention of joint infection. Once septic arthritis and anaemia coexist, the amount of blood necessary to restore the hemoglobin to normal is multiplied many times.

Internal skeletal fixation of a compound battle fracture is hazardous and almost always unnecessary. It is so important in the joints of the lower extremities to restore the normal weight-bearing alignment and to assure a normal axis of rotation, however, that fixation of large displaced articular fragments with bolts, screws, or pins seems justified, if closed methods are not successful. Systemic chemotherapy increases the safety of this procedure.

B. *Septic Arthritis*

If there are any symptoms or signs of infection on admission to a fixed installation, the wound must be inspected without delay. Drainage of an infected joint at the earliest possible moment is essential, if the joint is to be salvaged. Aspiration and irrigation with penicillin solution may eradicate infection in a small number of early cases, but it is dangerous to delay incision and drainage unless the signs of infection clear rapidly. Drainage must be radical, for experience has taught that infection can be eliminated only if drainage incisions are adequate to provide exposure of all recesses of the joint and to permit dependent drainage. If drainage has not been thorough, additional pockets of pus are almost certain to form and a septic course ensues, with eventual joint destruction.

The clinical picture of a patient with chronic septic arthritis is impressive. This was especially notable in the Chinese. In walking through the Chinese orthopaedic wards, one could usually tell at a glance the patients with joint infection by their "septic-arthritis facies". The emaciation, the drawn and waxen face, the unusual listlessness, and the apprehension were in striking contrast to the usual healthy appearance of the fracture patient. The temperature chart was characteristic,—septic in type, with a normal morning level and an afternoon or evening rise to from 102 to 104 degrees.

Penicillin was available for use in half of the cases of septic arthritis. Systemic penicillin therapy almost always improved the general condition of the patient, but the results of the local application of this drug to chronically infected joints were disappointing. Emphasis must be placed on the early institution of adequate drainage. Chemotherapy is only an adjunct to thorough surgery.

Foreign bodies which have perforated a joint and have lodged in adjacent bone present a difficult problem. If they are allowed to remain, bacteria are continually fed into the joint through the sinus tract, and a chronic septic arthritis results. These foreign bodies should always be removed, unless such an operation necessitates the destruction of considerable bone or cartilage.

Coincident joint involvement significantly increases the likelihood of osteomyelitis in a compound fracture. Twenty-seven per cent. of the patients with compound fractures

in this series developed bone infection,—a much higher incidence of osteomyelitis than occurred during this Campaign in compound fractures not associated with joint involvement.

Although many of the Russians [11] advocate resection of the joints in all early cases of septic arthritis and others [10] advise early resection if there is an associated fracture, the authors believe that, if early and adequate drainage is established and chemotherapy is employed, many joints will be saved and excellent functional results obtained, even if a fracture is present. This was our experience with several septic knee joints in which incision and drainage were done early. In late cases, however, when infection has become chronic and there is evidence of joint destruction, resection of the joint is the procedure of choice. The use of systematic chemotherapy following this procedure is essential to prevent spreading infection and septicaemia.

C. *Nerve Injuries*

The infrequency of nerve injuries in this series was surprising, in comparison with other reports. Irwin and Bailey [1], for example, found associated nerve injuries in 95 per cent. of wounds of the shoulder joint, while there was nerve paralysis in only one out of twelve shoulder wounds in this series. The high percentage of small missiles, with less destructive wounds, may account for this.

An associated nerve injury often produces greater disability than the joint wound. It is now generally agreed that severed nerves should be repaired within the first few weeks after injury, if optimum regeneration is to be obtained. The surgeon responsible for treating the joint wound must cooperate with the neurosurgeon in accomplishing this. If nerve regeneration does not occur, the involved joints may be fused in the position of election, or tendon transplantations may be performed.

D. *Mobilization*

The optimum time for starting motion of an injured joint has always been a point of contention among surgeons. In many instances, the immobilization required for an associated fracture greatly lengthens the time required for the joint alone. It has been the practice of the authors to shorten the usual period of immobilization of a fracture, if a contiguous joint has been injured. Motion must never be started, however, until there is clinical evidence of union. In clean joint wounds not associated with a fracture, immobilization was continued for about two weeks after the temperature had become normal. Physical therapy was then begun. If motion caused a return of fever, the joint was again immobilized. In infected joints, immobilization was continued for three weeks after all signs of infection had cleared.

Continued, regular, painstaking, *active* motion was found to be the most helpful measure in improving joint function. Passive motion should never be carried beyond the point of pain. Manipulation under anaesthesia was disappointing in the eight instances in which it was tried; a painful joint with diminishing function was the usual result. The authors believe that forceful manipulation should never be employed in these injuries.

Wedge plasters, however, were productive of more beneficial results, especially in the Chinese patients, many of whom refused to practise active exercises. A circular plaster was applied, with strips of flannel incorporated on the lateral aspects of the joint for hinges; an elliptical segment of plaster was removed from the side toward which it was desired that the distal limb of the joint be moved; and, on the opposite side, the plaster was split through one-third of its circumference so that increasing numbers of wooden blocks could be inserted daily, after the joint had been moved through its entire range of motion several times. This method has been used by Kirk for the correction of flexion deformities of the knees, following leg amputations.

PROBLEMS RELATED TO SPECIFIC JOINTS

Hip

Wounds of the hip are undoubtedly the most serious of all joint injuries, and the most disappointing to treat. In the eleven hip wounds in this series there were two deaths; septic arthritis developed in all; bony ankylosis occurred in five; and more than 50 per cent. of normal motion resulted in only one. Three patients (all Chinese) are still in the Hospital, more than a year after injury. Such poor results are obtained because (1) the joint is deep lying and difficult to expose, which often prevents thorough débridement and makes adequate incision and drainage most difficult, once infection has been established; (2) the precarious blood supply to the head of the femur is often destroyed by the injury, which leads to necrosis; and (3) the incidence of associated intra-abdominal injuries and injuries to the sciatic nerve is high.

The authors believe, however, that even these results are better than would have been obtained if early resection or disarticulation had been done in all instances, as is advised by Molodaya. Had earlier and more extensive drainage incisions been used in this series, preferably through the posterior approach recommended by Ober, the results might have been better. In several of our cases, incision and drainage were done only after irreversible damage had occurred. Once infection has become chronic and destruction of the joint has begun, the joint should be resected and the head and neck of the femur removed. Girdlestone has described a technique for this. Two incisions are used: One is behind and below the anterior superior spine, and through it the gluteal muscles are divided; and the second is at the base of the greater trochanter. The trochanter and its attached tissue are removed *en masse* so that the glutei are included. The hip joint and head and neck of the femur are then excised. The hip should be immobilized in the position of election for fusion: 15 degrees of flexion, slight abduction, and the neutral position of rotation.

When continued suppuration occurs in a hip joint and there is extensive osteomyelitis of the proximal part of the femur, Harmon and Adams believe that disarticulation may be advisable. If this is indicated, one must not delay operation until the patient's poor general condition makes the operation excessively hazardous.

Many orthopaedic surgeons [7] advise continuous traction for the treatment of septic arthritis of the hip in civilian practice. Acceleration of cartilage destruction by pressure of contiguous joint surfaces, which occurs when plaster immobilization is used, may be eliminated, it is thought, by traction. These cases, of course, are rarely due to gunshot wounds, and do not have extensive bone and soft-tissue damage. Although traction was used in only one of our patients, it seems likely that this is the preferable method. Only a moderate amount of traction should be used, because of the danger of dislocation. In addition, care must be taken to prevent deformities of adduction and external rotation, which are prone to occur. This can be done by keeping the thigh adducted at all times.

Knee

Wounds of the knee joint were by far the most frequent in this series, and in this group there was the highest percentage of good results. The joints were immobilized in a position of from 5 to 10 degrees of flexion by a circular plaster from groin to ankle. If there is an associated fracture of the femoral condyles, a single hip spica should be used. Quadriceps exercises must be begun early.

If septic arthritis develops, early and radical drainage must be instituted. Long parapatellar incisions, which expose both sides of the quadriceps pouch, are necessary. The patient should spend a part of each day in the prone position to facilitate anterior drainage. When the posterior compartment is involved, posterior arthrotomy is necessary. If the infection becomes chronic and joint destruction has begun, resection of the joint eliminates infection, causes earlier fusion, and shortens convalescence. This was done in three of our patients, with excellent results in all instances.

When an infected knee joint is associated with a fracture of the femur, a position of

moderate flexion (routinely employed for femoral fractures treated by traction methods) must be avoided in order to prevent a persistent flexion deformity. Immobilization must be in a position of from 5 to 10 degrees of flexion.

Injury of the patella did not appear to predispose to a poor result in these cases. Of the ten wounds of the knee joint in which the patella was involved, a good functional result was obtained in all. The quadriceps tendon had not been divided in any, and suture was not necessary. The patella was removed in three instances and, following suture of the quadriceps tendon, a good functional result was obtained in two and a fair result in the third.

Ankle

Although in only two of the eleven wounds of the ankle joint was more than 50 per cent. of normal motion regained, disability from this injury was not great. Infection was less difficult to control than in wounds of the hip and knee, and did not produce such a severe toxic reaction. When the joint was ankylosed in 5 degrees of plantar flexion and in the mid-position of pronation-supination, a surprisingly good functional result was obtained.

Shoulder

All wounds of the shoulder joint should be immobilized in a plaster spica, with the arm abducted 40 degrees and a little anterior to the plane of the body. Fusion in this position gives a fair functional result with the aid of scapular motion, and is preferable to a painful shoulder with some motion.

Elbow

Next to wounds of the knee, elbow wounds showed the best functional results. Half of the patients have obtained more than 50 per cent. of normal motion at this time. Infection is easily controlled, as a rule. Because of the superficial location of the joint, drainage is not difficult and sequestra are easily removed.

Forceful manipulation is especially harmful in elbow injuries. Continued active exercise is the most useful method of improving function, which may gradually increase over a period of years.

The optimum position for ankylosis depends largely upon the occupation of the patient. In the Chinese soldier, the ability to feed himself was probably most important, and the elbow was fused in a position of hyperflexion, with the forearm in slight supination. In this position, the palmar surface of the hand is most easily brought to the mouth.

Buxton advises immobilization of suppurating elbow joints at a right angle, with the forearm in full supination; he maintains that in this position suppuration does not tend to spread along fascial or intermuscular planes. If ankylosis occurs, however, this position may not be optimum for the patient. It seems preferable to immobilize all suppurating joints in the position of election for fusion.

MORTALITY

Two of the three deaths were probably not preventable. One occurred in an American soldier, struck by a twenty-five caliber bullet, which perforated the left hip joint and rectum and emerged posterior to the sacrum. A laparotomy was done at a forward hospital, with negative findings. The patient arrived at this Hospital twenty-four hours after injury in desperate condition, with signs of overwhelming peritonitis, which caused his death. The other death was due to a pulmonary embolus, following incision and drainage of an infected hip joint on the eighteenth day after injury. The wound had not been debrided until four days after injury and the patient, a Chinese soldier, was admitted to this Hospital with severe septic arthritis.

The third death occurred in a Chinese soldier, who received a perforating bullet wound of the left knee twenty-four hours before admission. The wound had been debrided within three hours after injury, and appeared clean on admission. There were incomplete

fractures of the distal end of the femur and proximal end of the tibia, but no foreign bodies were present. Because of a septic condition and fever, he was given oral sulfadiazine and intramuscular penicillin; but incision and drainage were not done for seven days. This operation was not extensive enough, and the development of additional pockets of pus necessitated further incisions. Repeated blood cultures recovered *Bacillus pyocyaneus*. The septic condition continued, and the patient died on the twenty-eighth day after injury. Earlier and more thorough operation should undoubtedly have been done. When the infection did not respond to these measures, amputation might have been life saving. Had the causative organism, *Bacillus pyocyaneus*, not been resistant to the sulfonamides and penicillin, the infection could probably have been controlled.

RESULTS

The end results of joint injuries cannot be evaluated accurately unless the patient can be followed for several years. The remarkable improvement in several of the Chinese patients, examined at a rehabilitation camp about a year after injury, was very enlightening. The delayed improvement shown by these patients, and the relatively high percentage of good results in wounds of the knee and elbow obtained before discharge from this Hospital, lead to the belief that early amputation or early joint resection is rarely, if ever, justifiable.

CONCLUSIONS

1. One hundred thirty-four gunshot wounds of the major joints, treated during the North Burma Campaign, have been analyzed.
2. Disability of some degree—due to chronic arthritis, fibrous or bony ankylosis, and associated nerve injury—is relatively common.
3. The most important measure in the treatment of these injuries is early and thorough débridement. Closure of the capsule, after a thorough débridement, is probably helpful in preventing infection of the joint. If there is any doubt about the adequacy of the débridement or removal of all foreign bodies, the capsule should not be closed.
4. Septic arthritis, which occurred in one-third of these patients, is a serious complication. Early arthrotomy, with radical incisions to provide adequate drainage, will salvage many joints and is preferable to early resection.
5. Chronically infected joints, in which fusion is inevitable, should usually be resected.
6. Amputation for septic arthritis is rarely justified, but may at times be life saving.

REFERENCES

1. Bailey, H., Editor: Surgery of Modern Warfare, Vol. II, Ed. 2. Edinburgh, E. and S. Livingstone, 1942.
2. Bowlby, A.: Fractures of the Femur at the Casualty Clearing Station. British J. Surg., **3**: 626–631, 1915–16.
3. Buxton, St. J. D.: Gunshot Wounds of the Elbow-Joint. Lancet, **2**: 663–665, 1943.
4. Churchill, E. D.: The Surgical Management of the Wounded in the Mediterranean Theater at the Time of the Fall of Rome. Ann. Surg., **120**: 268–283, 1944.
5. Fruchaud, H.: Wounds of the Joints. Lancet, **2**: 235–238, 1944.
6. Girdlestone, G. R.: Acute Pyogenic Arthritis of the Hip. An Operation Giving Free Access and Effective Drainage. Lancet, **1**: 419–421, 1943.
7. Harmon, P. H., and Adams, C. O.: Pyogenic Coxitis. I. End-Results and Considerations of Diagnosis and Treatment. Surg., Gynec., and Obstet., **78**: 371–390, 1944.
8. Harmon, P. H., and Adams, C. O.: Pyogenic Coxitis. II. Indications for Surgical Treatment in Residual and Chronic Stages and End-Results of Reconstruction in 53 Patients. Surg., Gynec., and Obstet., **78**: 497–508, 1944.
9. Kirk, N. T.: Amputations. *In* Lewis' Practice of Surgery, Vol. III, Chapter X, Hagerstown, Maryland, W. F. Prior Co., Inc., 1945.
10. Molodaya, E. K.: Treatment of Gunshot Wounds of Large Joints. Khirurgiya, No. 1, pp. 12–20, 1944.
11. Watson-Jones, R.: Russian Surgeons and Russian Surgery. British Med. J., **2**: 276–277, 1943.

FRACTURES OF THE HEAD OF THE RADIUS

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Medical Corps, Army of the United States

The relatively high incidence of fracture of the head of the radius, seen by the authors in the course of ten months, seems worthy of note. All fractures were the result of so-called minor accidents (falls from bicycles, ladders, or wings of planes, or simple falls during the black-out) sustained on various Army Air Corps bases in the vicinity. This fact has facilitated excellent follow-up studies.

INCIDENCE

In a ten-month period the authors have treated forty-two simple, acute fractures of the head of the radius. In this same period they have recorded ten simple fractures of the neck of the radius, three Colles's fractures and two Smith's fractures of the distal end of the radius, and 100 simple fractures of the carpal scaphoid. No complicated cases, such as those associated with dislocation of the elbow or Monteggia's type of fracture, are included in this series.

ANATOMY

Grossly, the head of the radius presents a type of bony structure similar to that seen in the patella, with the columnar type of dense cancellous bone running longitudinally. This explains the plane of the fracture, which is always longitudinal. The absence of periosteum about the head has been noted. The "ligamentum capituli radii" (as we have chosen to call the posterolateral continuation of the attachment of the quadrate ligament which is covered by a distinct fold of synovial membrane) is shown in the inset to Figure 1; and because at its base it envelops over a third of the circumference of the neck, it can be used at the time of operation (see section on *Surgical Technique*). The relationship of the annular ligament and the deep branch of the radial nerve is also shown.

The articulation of the head of the radius with the capitulum of the humerus is such

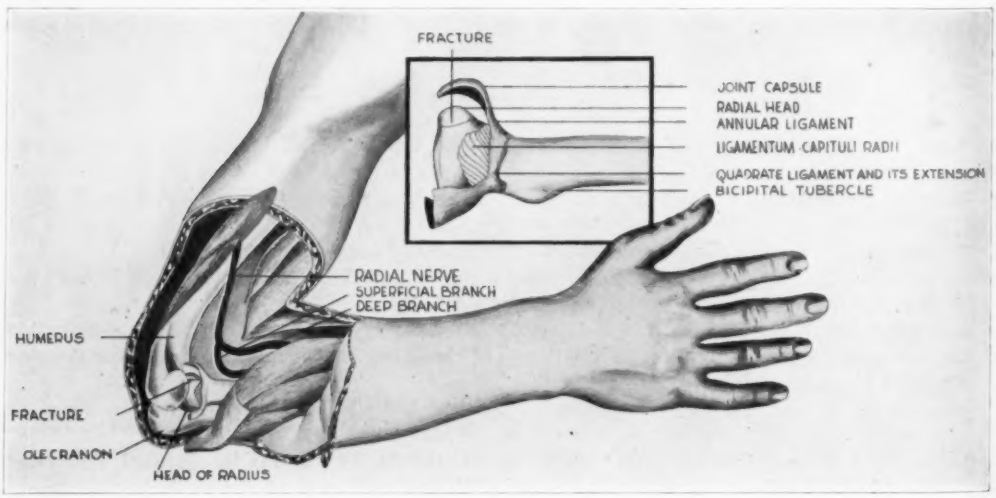

FIG. 1

Lateral view of the partially dissected right elbow joint, showing relationship of the radial nerve to the annular ligament. Inset shows the ligamentum capituli radii as a continuation of the quadrate ligament (from a dissected specimen, Cambridge University Medical School, Cambridge, England). Note relationship of bicipital tubercle to the fracture, with the forearm pronated.

that this joint acts primarily as a stabilizer at the elbow joint for abduction strains (pressure applied upward through the hand on the valgus elbow, with the carrying angle varying from 5 to 20 degrees). The head moves across the capitulum during flexion and extension of the elbow, but the actual rotation of the forearm on the ulna through approximately 120 to 160 degrees, by means of the articulation with the radial notch, demands approximately exact anatomical reposition of the fragments of the head in order to retain full supination and pronation.

TYPES OF INJURIES

Invariably the history in these cases is that of attempting to break a fall, either forward or backward, by taking the weight on the outstretched hand, with the elbow flexed slightly and the forearm partially pronated. This results in a cubitus valgus force, transmitted through the head of the radius to the capitulum of the humerus, fracturing the anterolateral segment of the head. This is shown in Figure 2, in which the fracture appears on the anteromedial side of the joint, with the hand partially pronated. The degree of leverage and the resulting angle at which the capitulum is driven into the pronated head of the radius determine the degree of comminution and displacement.

FIG. 2

FIG. 3

Fig. 2: Type I fracture with forearm in pronation (the position at time of injury), showing relationship of the fractured segment to the capitulum of the humerus.

Fig. 3: Type I cleft fracture. Note persistence of fissure ten months after injury.

The associated trauma to the capitulum is not frequently seen roentgenographically, but it is often seen surgically. Late changes of the capitulum and lack of bony repair of the crack fracture of the head of the radius (Type I) are shown in Figure 3. That the abduction force also injures the medial portion of the capsule is shown by the fact that, even late in the follow-up, the patient will in some cases complain of discomfort about the medial aspect of the elbow joint.

TYPE OF FRACTURE

Fractures of the radial head have been divided into three classes. Type I includes the mild case with a simple crack fracture (chisel type or cleft fracture), in which a brief abduction force is applied to the anterolateral segment of the head against the capitulum of the humerus (Fig. 2). This results in either a single cleft across the head longitudinally, without depression (Fig. 3) or with slight depression (Fig. 4), without actual increase in circumference of the head. This type does well with conservative therapy.

FIG. 4

FIG. 5

Fig. 4: Type I cleft fracture, with slight depression of the anterolateral segment.
Fig. 5: Type II fracture, with comminution and some displacement.

FIG. 6

FIG. 7

Fig. 6: Type III fracture, showing severe comminution of the entire head of the radius.
Fig. 7: Type III fracture, showing severe comminution with displacement.

Type II comprises those fractures in which the circumference of the head has been increased moderately by comminution or disturbed by marginal displacement of the anterolateral segment (Fig. 5). The question of surgical excision most frequently arises in the treatment of this group; we feel, however, that all of these cases should be treated conservatively.

Type III includes those fractures with marked displacement of one or more bony fragments (Fig. 7). The authors feel that all of these cases should be treated by early surgery.

TREATMENT

Conservative treatment in the first type of fracture means merely the use of a sling, with or without aspiration of fluid from the elbow joint. Aspiration is indicated when the joint is tense, and had best be done twenty-four hours after injury, at which time the

FIG. 8-A

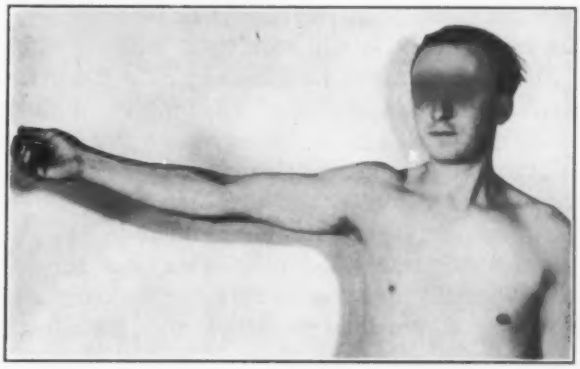

FIG. 8-B

FIG. 8-C

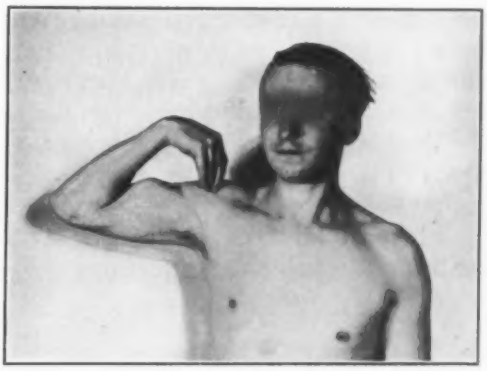

FIG. 8-D

Patient with Type III fracture, six months after operation. Show full range of painless motion.

active bleeding usually has ceased. This procedure may have to be repeated. Relief of pain is quite remarkable, and the patient is thus encouraged to begin earlier motion. The use of a sling for a week or ten days adds to the comfort.

Conservative therapy in the second type of case consists of the treatment just mentioned or, in the more comminuted type, a period of ten days to two weeks in a plaster splint with the elbow at right angles and the forearm in neutral position. This is followed by a sling and active motion, with physical therapy, consisting of heat and mild massage daily. In two of the patients in this group, aspiration was done, and no difference was noted in the end results.

The third type is treated by early surgical excision of the entire head. The authors believe that surgery in the first week offers the best chance for the initial healing of these injuries. It saves the patient's time, and the joint can resume its function early. On several occasions the decision was made preoperatively to remove only the small fragment demonstrated roentgenographically, but so much comminution was found at the time of operation that the entire head was resected.

SURGICAL TECHNIQUE

The surgical technique consists of a lateral incision; a sphygmomanometer cuff, set at 200 millimeters of mercury, is used as a tourniquet. The incision extends from the lateral epicondyle through the conjoined tendon of the extensor digitorum communis and the extensor carpi ulnaris muscles. This incision is about two inches long and extends down to, but not beyond, the annular ligament. Care should be taken not to cut or to injure the deep branch of the radial nerve by traction on the mass of supinator muscle. Adequate

exposure of the joint can always be obtained by going to, or proximal to, the epicondyle. Inspection of the lateral joint space will invariably demonstrate much more comminution of the head than was visualized by roentgenogram, and will also reveal the trauma to the cartilage of the capitulum of the humerus. With the forearm fully pronated, the triangular ligament, referred to in the section on *Anatomy* as ligamentum capituli radii, comes into full view through the incision. Its relationship to the bicipital tubercle and to the fracture is shown in Figure 1, and has been confirmed at the anatomy table. By means of an osteotome, the ligamentum capituli radii is stripped down to where it blends with the synovial reflection, which offers a flap that can be sutured across the raw stump. A stump with a smooth neck can be obtained by using a sharp osteotome, held rigidly at the base of the head, proximal to the annular ligament. Frequent light tapping, together with rotation of the forearm through its 150 degrees, will leave a smooth cut instead of the minute bony fragments which result from the use of a Gigli wire. Any shredding of the cartilage over the capitulum is now pared down, and further inspection of the lateral joint compartment is readily performed. The humero-ulnar joint is visualized, and any interposing fragments can be removed. The previously reflected ligamentum capituli radii is now sutured across the smooth neck, covering it completely. The synovial membrane and the capsule are closed as one layer, the split conjoined tendon as another, and the skin as the third layer. Dressings, sterile sheet wadding, and a plaster cast, which holds the arm flexed to 90 degrees and the forearm in neutral position, complete the procedure. After two weeks the cast and the skin sutures are removed and active motion is begun, encouraged by physical therapy. The sling is discarded after two weeks, and the patient is ready for light duty at the end of four or five weeks.

END RESULTS

In this series of forty-two cases, twenty-eight (66.6 per cent.) were Type I, five (12 per cent.) were Type II, and nine (21.4 per cent.) were Type III. Twenty-two (52.4 per cent.) involved the head of the left radius and twenty (47.6 per cent.) involved the right. Thirty-three cases were treated conservatively and nine cases were treated by surgical excision. Table I shows the three types and the clinical findings.

Of the thirty-three cases treated conservatively, eight (24.2 per cent.) demonstrated

FIG. 9

FIG. 10

Fig. 9: Resected radial head, six months after operation. Note absence of any bone reaction.

Fig. 10: Type I fracture, showing roughening of the capitulum humeri and lack of bony repair of the cleft. (Patient had history of "sprain" one year before.)

TABLE I

CLINICAL FINDINGS IN THREE TYPES OF FRACTURE

Type of Fracture	Patients with Normal Range of Painless Motion	Patients with 5 to 10 Degrees of Limitation in Extension and Supination		
		Without Pain	With Discomfort in Extremes of Motion	With Discomfort in Extremes and Tender Medial Joint
I	9	13	3	3
II	1	2	0	2
III	7	2	0	0
Totals	17	17	3	5

minimum limitation of motion, with discomfort in attempts at full supination or full extension. This was not severe, as none of the patients reported back to the clinic with this complaint. In contrast, when checked at the end of six months, none of the patients operated upon had any discomfort and actually showed a better range of motion (Figs. 8-A to 8-D) than some of the patients who had not been operated upon.

Bony spurs and myositis ossificans were absent in this series of cases. The cleft in the Type I cases persisted without any evidence of bone repair, even after ten months and a year, respectively (Figs. 3 and 10).

Temporary palsy of the radial nerve developed in one patient postoperatively as a result of the sphygmomanometer cuff, but recovery was complete in seven weeks. No symptoms about the wrist developed in any case.

DISCUSSION

This study has presented several problems. The limitation of motion (with or without pain) in the patients who were not operated upon has been attributed to the radial head; and yet, after surgical excision (either early or late), this limitation of motion was not altered in some cases.

Reference to the medial portion of the joint in the form of discomfort about the capsule was observed in three cases of Type I and two cases of Type II. This was explained on the basis of the abduction strain placed on this side by the initial trauma; and yet those patients of Type III with a similar, but usually more severe, abduction strain on the medial capsule did not complain. This was explained on the basis that the force was dissipated by collapse of the head. Late roentgenograms disclosed no bony disturbance in this region (Figs. 3 and 10). The question is occasionally raised of pain referred to the wrist, secondary to these fractures. We saw no such cases in this series, but have had the occasion, repeatedly, to observe the absence of clinical or roentgenographic evidence of trauma to the distal portion of the radio-ulnar joint. This seems best explained as referred pain. The innervation of the wrist joint by the terminal branches of the deep branch of the radial nerve, irritated in the region of the head of the radius, seems logical.

The question of support and rest of the part with the use of a plaster splint, which was used in two of the Type II cases because they seemed to be more severe, was answered when they were followed up. These patients did as well as those who were treated by the sling method.

Subsequent roentgenographic studies have shown no cases of osteochondritis dissecans involving the elbow joint, but Figure 10 presents evidence of the trauma to the capitulum humeri. The absence of any attempt at repair of the cleft type of fracture (Type I) is best explained on the basis of an intra-articular fracture.

Of the patients in Type III upon whom operation was performed, the absence of bony spurs about the stump of the neck of the radius is probably due to the method described for covering the stump.

SUMMARY

1. A series of forty-two cases of simple fracture of the head of the radius is presented, in which thirty-three cases (Types I and II) were treated conservatively, with excellent end results in 75 per cent. The remaining 25 per cent. showed a mild degree of disability.

2. Nine cases (Type III) were treated by total excision of the head of the radius, with excellent end results.

NOTE: The authors wish to express their thanks to Professor H. A. Harris and his staff of the Anatomy School at Cambridge University, Cambridge, England, for assistance.

A CASE RESEMBLING HEMANGIOMATOSIS OF THE LOWER EXTREMITY

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The case recorded here presents a problem in diagnosis. A report of a similar case has not been found. The microscopic picture of the lesion suggests that it involves the capillary system, and the title was selected for this reason. On gross examination, however, no extraneous blood vessels were encountered. Although both bone and soft tissue were involved, the primary lesion appeared to surround the great vessels of the limb.

Irradiation was tried empirically. The favorable response has led the roentgenologist to feel that the lesion may be some type of malignant radiosensitive tumor. Microscopic examinations show no such evidence, however.

CASE REPORT

C. P., an eleven-year-old white boy, was in his usual state of good health until April 1941, at which time he fell from his bicycle and hurt his left knee. The region of the knee joint became swollen and

FIG. 1

Roentgenograms taken on April 17, 1942, show a lesion which involves the distal third of the femur. There is marked soft-tissue swelling. Destructive changes of lower third of femur do not involve the epiphysis. A pathological fracture is present.

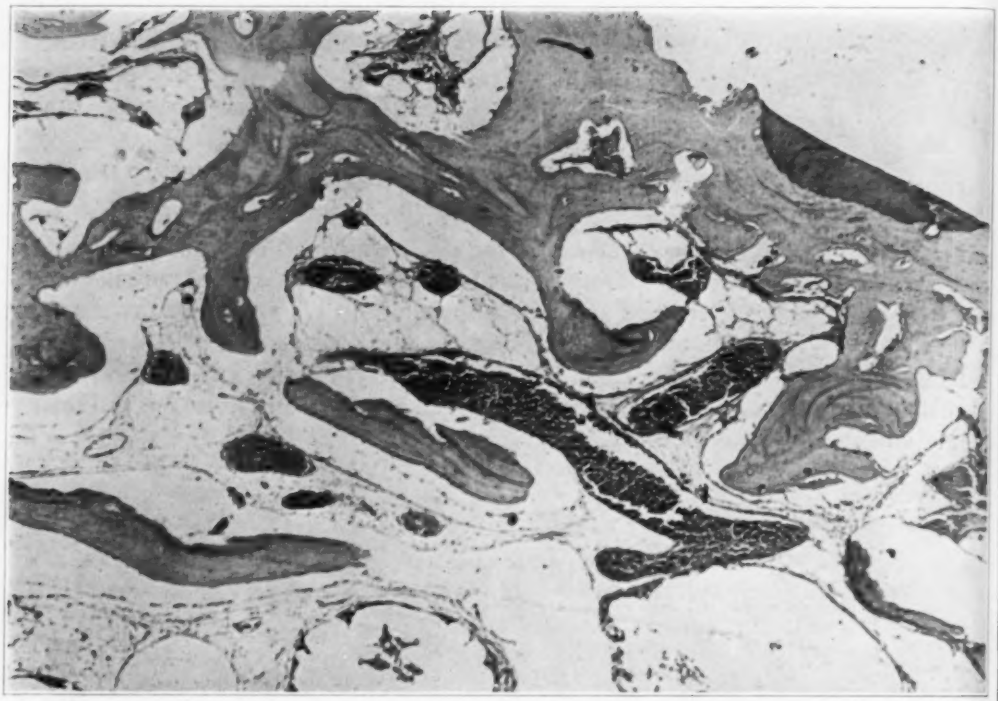

FIG. 2

Microscopic section of femur shows osteoporosis of bone. There is a sprouting of capillary blood vessels, which is most evident where the trabeculae are thin and widespread.

discolored, and it was warmer than the other knee. He was treated conservatively by his doctor and in ten days was walking about with no pain, but the swelling and discoloration did not subside.

In May 1941, roentgenograms were taken because the swelling persisted. They showed no pathological changes of the bone. Roentgenograms were taken again in July, because the swelling and discoloration appeared to be increasing. Again no involvement of the bone was revealed.

It was then noted that the swelling and discoloration were spreading gradually above and below the knee. In February 1942, while turning over in bed, the patient experienced pain for the first time since the onset of his illness. After this, swelling soon involved the thigh and the upper half of the leg.

In April, he was admitted to the Orthopaedic Service of the Hospital of the University of Pennsylvania. His temperature, pulse, and respiration were normal. He was pale and undernourished. The left lower extremity was involved in a generalized swelling. The regions above and below the knee were discolored, and the skin temperature was elevated. A fluctuant wave, involving the thigh and the upper half of the leg, could be demonstrated. All arterial pulsations were normal.

The laboratory studies were as follows:

Hemoglobin	80 per cent.
White blood cells	7,500
Polymorphonuclear neutrophils	54 per cent.
Lymphocytes	32 per cent.
Monocytes	5 per cent.
Eosinophils	7 per cent.
Basophils	2 per cent.
Blood calcium	10 milligrams per 100 cubic centimeters
Blood phosphorus	3.5 milligrams per 100 cubic centimeters
Sedimentation rate	5 millimeters per hour
Coagulation time	4 minutes
Bleeding time	3 minutes

The blood phosphatase was elevated to 18.2 Bodansky units. A urinalysis was negative, Kolmer and Kahn tests were negative, and the tuberculin test was negative. Fifteen hundred cubic centimeters of thin serosanguineous fluid was aspirated from the thigh subfascially. Laboratory studies of the fluid

showed it to be negative on culture and smear. Microscopic examination of the sediment showed only red blood cells and blood pigment, with some round lymphoid-like cells.

On April 17, all the bones in the body were normal by roentgenogram, except the left femur (Fig. 1). At the distal third of the left femur was a lesion characterized by marked soft-tissue swelling and destruction of the bone. There had been a pathological fracture.

A provisional diagnosis of hemangioma of the lower end of the femur was made, and it was decided to examine the lesion at operation and to amputate the limb. This was done in May 1942 by A. Bruce Gill, M.D. The lower end of the thigh was incised. Bloody fluid gushed out, and then a network of white tissue was noted. This involved the subcutaneous tissue and muscles, and extended into the bony fragments, which were markedly osteoporotic. The tissue also surrounded the large blood vessels. This tissue, which resembled nerve tissue, varied in thickness and was continuous. On gross examination, no lumen was evident and no blood could be expressed from the tissue. A mid-thigh amputation was performed, and the lesion was resected as high as possible. The remaining ends of the lesion, which were at the level of the tourniquet, were ligated.

Examination of the specimen showed that the subcutaneous tissue in the region of the discolored skin was indurated and stained with blood pigment. The fascial layers and the septa were shredded, giving rise to continuous long, white strands of varying thicknesses. This condition extended from the subcutaneous tissue down to the bone, and involved the periosteum. Surrounding the large vessels, these strands were so fine and thin that they gave the appearance of spider-webbing. Between the muscles the strands were thicker, often reaching the size of small vessels or nerves. The bone was markedly porous and broke easily. It had the appearance of bone which had been decalcified by soaking it in a solution.

FIG. 3

Roentgenogram taken July 16, 1942, shows further destruction of upper end of femur and questionable involvement of the acetabulum.

FIG. 4

Roentgenogram of February 26, 1943, shows greater destruction of femur. Punched-out areas are increasing. The region of the ilium above the acetabulum also shows punched-out destructive areas.

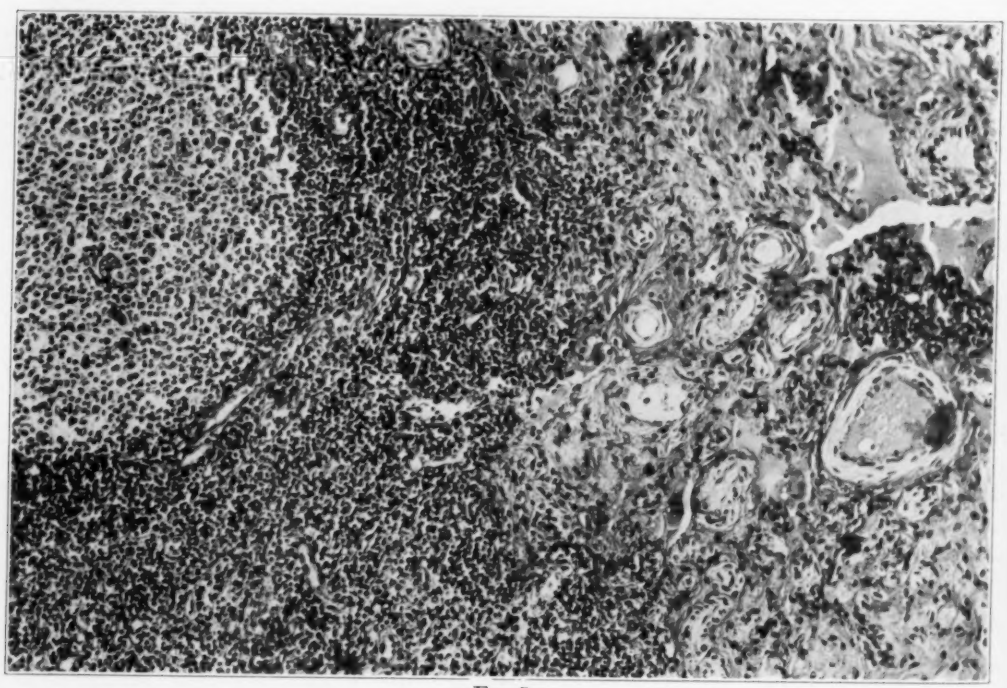

FIG. 5

Microscopic section of soft tissue shows fibrous tissue, fat, and a large number of capillary vessels. The vessels appear to be of the venous type. There is extensive fibrosis. Note the focal aggregation of lymphoid cells.

The microscopic section of the femur showed considerable osteoporosis. The number of capillary blood vessels was greatly increased. This was most evident where the trabeculae were thin and widely spaced (Fig. 2). The soft-tissue sections showed fibrous tissue and thin-walled blood vessels.

The patient was discharged on June 19, 1942, with the stump healed, but boggy. His progress was followed in the Out-Patient Department. He got along well and gained weight. Roentgenograms in July showed questionable progression of the disease (Fig. 3). In November, roentgenograms showed increased decalcification and punched-out areas in the femur and acetabulum. In February 1943, he noted that the stump was becoming discolored. This was followed by swelling, and roentgenograms showed that now the head of the femur and the pelvis were involved (Fig. 4).

The patient was readmitted to the Hospital. A roentgenographic survey of the bones was again negative, except for the left hip and the stump. All laboratory studies were repeated, and found to be not remarkable, except for an elevated phosphatase (17.7 Bodansky units). On April 14, 1943, biopsy of the lesion in the left groin was performed by Paul C. Colonna, M.D. Again the plexiform mass surrounding the great vessels was encountered. A great deal of bloody-watery fluid flowed freely from the wound. The soft tissues appeared to be disintegrating, as they absorbed the fluid. Tissue was removed for examination.

Microscopically, the section showed an increased number of blood vessels, but they contained very little blood; their walls were thin, but development appeared to be normal. There was extensive fibrosis in the surrounding areolar tissue. The most striking feature, however, was the focal aggregation of lymphoid cells, sometimes grouped about well-organized germinal centers (Fig. 5).

Sections were made of eight different parts, and they were examined by Robert C. Horn, M.D., Surgical Pathologist of the Hospital of the University of Pennsylvania; Joseph McFarland, M.D., Professor Emeritus of Pathology of the University of Pennsylvania; William E. Ehrich, M.D., Pathologist of the Philadelphia General Hospital; and Arthur Purdy Stout, M.D., Associate Professor of Surgery, Columbia University, College of Physicians and Surgeons, New York City. All of these men considered the lesion to be some type of angioma.

FIG. 6

Roentgenogram taken July 7, 1944, about ten months after roentgenotherapy had been stopped and twenty-six months after amputation, shows definite improvement. Calcification of punched-out areas is occurring. The disease process has definitely been arrested.

Horn reported as follows: "The sections made from the amputated leg show essentially a sprouting of capillary blood vessels, which is most evident in the bone, where the trabeculae are thin and widely spaced. Minor degrees of old and recent hemorrhage are associated with this vascular growth in the soft tissues. The sections made later at biopsy again showed increased numbers of blood vessels. The vessels here, however, tend to be of larger caliber and often have well-developed muscular walls of venous type. These vessels contain little blood. There is extensive fibrosis in the surrounding areolar tissue, but the most striking features are focal aggregates of lymphoid cells, sometimes grouped about well-organized germinal centers.

"Although the nature of this lesion is obscure, there is little doubt, on the basis of pathological examination, that neoplasm can be ruled out. (Stout agrees with me on this point.) The only suggestion I have to offer is that the changes are associated with disease (anomalous or otherwise) of the general vascular system of the leg.

"I have observed clinically and studied pathologically at the Presbyterian Hospital in New York City the case of a boy whose lesion, consisting essentially of a widespread sprouting of capillaries, presented many similarities to this case. Detailed study of that case brought to light the clinical finding of multiple small arteriovenous anastomoses; and the pathological finding of small peculiar blood vessels, which bore some similarities to arteries and some to veins. Of course, it is not known whether or not these changes were of a primary or secondary nature.[1]

"As to nomenclature, I can suggest only 'hemangiomatosis', a term without a great deal of meaning, which would, however, suggest the sprouting of blood vessels which characterizes the lesion and indicates its non-neoplastic nature."

The wound healed *per primam*. The bogginess of the stump persisted. After consultation with members of the Radiology Department, it was decided to give the patient a course of roentgenotherapy.

Between April 20 and May 27, 1943, the patient was treated with 200 kilovolts of x-ray radiation with an added filtration of 0.5 millimeter of copper, and one millimeter of aluminum with half-value layer of 1.05 millimeters of copper. The patient received 200 roentgen units to each of two portals daily, at a distance of 50 centimeters. There was an anterior portal, 15 centimeters by 15 centimeters, directed to the left ilium, the acetabulum, and the head and neck of the left femur. There was a similar posterior portal. There were also anterior and posterior portals, 10 by 13 centimeters, that covered the upper half of the femur, below the portals previously described. Each portal received 1700 roentgen units, measured in air.

The patient was followed in the Clinic, and periodic roentgenographic examinations were performed. His general condition was good. The bogginess in the stump disappeared after about six months. The roentgenograms showed progressive improvement. The punched-out areas appeared to be filling in, as was evident from films taken in July 1944 (Fig. 6). The Radiology Department feels that roentgenotherapy is no longer indicated. The fitting of a prosthesis is now being considered.

A satisfactory diagnosis for this puzzling case has not been established.

1. Stout, A. P.: Tumors of Blood Vessels. Texas State J. Med., **40**: 362–365, 1944–45.

EOSINOPHILIC GRANULOMA OF BONE

Report of a Case Involving the Clavicle

BY LIEUTENANT COLONEL R. BEVERLEY RAY AND MAJOR AARON KELLNER

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The clinicopathological entity of "eosinophilic granuloma of bone" was described by Lichtenstein and Jaffe in 1940. Independently and almost simultaneously, the same picture was described by Otani and Ehrlich under the name of "solitary granuloma of bone". Similar cases were reported by Farber and by Green and Farber, who used the term "destructive granuloma of bone". The subject was well reviewed by Jaffe and Lichtenstein in 1944, and the basic relationship between Hand-Schüller-Christian disease, Letterer-Siwe disease, and eosinophilic granuloma of bone was stressed. To date, between thirty and forty cases of eosinophilic granuloma of bone have been reported. In this paper the authors wish to report an additional case involving the clavicle. This is a rare site for the occurrence of the condition, but one case was reported previously by Greenberg and Schein.

CLINICAL FEATURES

Eosinophilic granuloma of bone is clinically and histologically a benign inflammatory lesion. It is found almost exclusively in children, adolescents, or young adults. The lesions may be single or multiple and may involve the long bones or flat bones, or both. The clinical picture is usually that of local swelling, tenderness, redness, heat, and pain with some limitation of function, depending upon the bones involved. Systemic manifestations—such as fever, malaise, weight loss, leukocytosis, or eosinophilia—have been noted, but are rare. The lesions frequently produce no symptoms, and are discovered only by roentgenographic examination.

ROENTGENOGRAPHIC APPEARANCE

The roentgenographic picture consists essentially of an area of bone destruction. The bone may be expanded and the cortex eroded or perforated. Periosteal new bone is occasionally seen. Lesions in the skull may be sharply punched out. Sclerosis of bone about the lesion is unusual, unless pathological fracture has occurred. The roentgenographic appearance is by no means pathognomonic, and can mimic a wide variety of benign and malignant neoplasms and inflammatory lesions of bone.

PATHOLOGICAL FINDINGS

In the early stages, the gross appearance is that of soft hemorrhagic granulation tissue, which may be brown or yellowish in color and may contain areas of necrosis. The histological picture is that of a destructive granulomatous lesion, characterized by variable numbers of large mononuclear histiocytes which are actively phagocytic, interspersed among which are collections of eosinophils. The histiocytes are considered by Jaffe and Farber to be the basic component of the lesion. The eosinophils may be quite sparse, but are often present in large sheets and may present a striking red appearance in sections stained by the hematoxylin-eosin method. In some areas small numbers of lymphocytes, plasma cells, polymorphonuclear leukocytes, and multinucleated giant cells are found.

As the lesion progresses the eosinophils tend to disappear, according to Green and Farber, and the cytoplasm of the histiocytes becomes foamy, so that they take on the appearance of lipophages or "xanthoma" cells. In later stages the lesion undergoes fibrosis

and eventual transformation into bone. Jaffe and Lichtenstein are of the opinion that the disease may heal by resolution, without passing through a lipogranulomatous stage.

ETIOLOGY

The etiology of the condition is obscure. It is generally believed that the disease is of an inflammatory nature, although no specific causative micro-organism or virus has been isolated. Otani was of the opinion that trauma played a role in the pathogenesis.

TREATMENT AND PROGNOSIS

Therapy for eosinophilic granuloma has been empirical, but satisfactory. Jaffe states that the lesions may undergo spontaneous healing within from a few months to a year. Excision or curettage has been followed by complete cure with no local recurrence, although new lesions have simultaneously or subsequently appeared in other sites. Relatively small doses of roentgenotherapy have been employed, with good results.

The prognosis in general is good. In those cases with multiple bone lesions, however, there may be visceral lesions which would put the diagnosis in the category of Hand-Schüller-Christian or Letterer-Siwe disease, where the prognosis is more guarded.

CASE REPORT

An aviation cadet, twenty-two years of age, was admitted to the Army Air Forces Regional Hospital, Westover Field, on August 24, 1944, after transfer from a near-by Station Hospital. Four weeks prior to admission he first noted pain, tenderness, and enlargement of the left clavicle, approximately one inch from the sternal end. Three or four days after the onset of pain he consulted a medical officer; heat treatment and special calisthenics were given for one week. Because of persistent pain, increase in tenderness, and localized swelling, he was admitted to the Station Hospital at his base, where roentgenograms were taken. A destructive lesion was noted in the left clavicle, and a diagnosis of acute osteomyelitis of the clavicle was made. The patient was then transferred to this Hospital for definitive treatment. Upon arrival, he stated that the clavicular mass was never red or hot; it had definitely increased in size during

FIG. 1

Roentgenogram showing destructive lesion of the left clavicle. (*Base Photographic Laboratory, Westover Field, Massachusetts.*)

the present illness, and much more rapidly during the past one or two weeks. During the past month or six weeks he had lost from four to six pounds in weight, which he attributed to the strenuous training program of the aviation cadets. He had occasional headaches during his present illness, but no other systemic symptoms and no symptoms referable to any other portion of the skeletal system. There was no history of trauma to the affected bone. The patient's past history was not remarkable. He had been in the Army for one and one-half years at the time of admission, and had had no overseas service. His family history was relevant only in that his mother had died of what was thought to be pulmonary tuberculosis, but there was no family history of malignant or neoplastic disease.

On physical examination he was found to be a rather thin white male, seventy-one inches in height, and weighing 137 pounds. A general physical examination was negative with the exception of the left clavicle, in which there was a tender fusiform mass, one inch from the sternal end. This mass was approximately two by two centimeters in extent, was not fluctuant, did not pulsate, and did not show signs of acute inflammation. Shoulder motion and motion of the sternoclavicular joint were normal. The lymph nodes of the neck were not enlarged, but in the left axilla there was a firm, non-tender, palpable lymph node, one centimeter in diameter, which the patient stated had been tender and enlarged approximately two weeks prior to admission. There was no reaction in the skin about the clavicular mass, and no tenderness or evidence of bone involvement in the rest of the skeletal system. There were no neurological abnormalities, and the chest was clear to percussion and auscultation.

Laboratory Data

Blood Count:	Red blood cells	4,910,000
	Hemoglobin	98 per cent. (Sahli)
	White blood cells	7,900
	Polymorphonuclear neutrophils	61 per cent.
	Eosinophils	2 per cent.
	Lymphocytes	37 per cent.
Blood Chemistry:	Total serum proteins	6.4 grams per 100 cubic centimeters
	Albumin	3.9 grams per 100 cubic centimeters
	Globulin	2.5 grams per 100 cubic centimeters
	Calcium	10.7 milligrams per 100 cubic centimeters
	Inorganic phosphorus	3.1 milligrams per 100 cubic centimeters
	Phosphatase (alkaline)	3.7 Bodansky units
	Sugar	140 milligrams per 100 cubic centimeters
	Uric acid	2.9 milligrams per 100 cubic centimeters
	Cholesterol	206 milligrams per 100 cubic centimeters
	Non-protein nitrogen	37.5 milligrams per 100 cubic centimeters

The sedimentation rate was two millimeters per hour (Westergren). The Kahn test was negative. A urinalysis was negative, including a test for Bence-Jones proteins.

Roentgenographic Examination

Views of the left clavicle (Fig. 1) showed a transverse irregular elliptical area of bone absorption, measuring two centimeters by one centimeter and involving the upper two thirds of the clavicle, four centimeters from the sternal end. The edge of the defect was scalloped, hazy, and moth-eaten in appearance, with absorption through the upper cortex, leaving a residual small angular shelf, laterally and superiorly. There was no sequestration, no sclerosis or bone condensation, and no trabeculation, but slight cortical expansion was noted. An overlying soft-tissue mass, measuring approximately 2.5 centimeters by 1 centimeter, was present. Overlying the defect was a thin, opaque, elliptical rim of calcification. In comparison with roentgenograms taken twelve days previously at the Station Hospital, a definite increase in bone destruction was seen. The roentgenographic appearance was considered indicative of a neoplasm, probably malignant, rather than of osteomyelitis or other non-neoplastic condition, such as parathyroid disease. Roentgenograms of the thoracic spine, ribs, skull, lumbosacral spine, pelvis, both femora, both tibiae and fibulae, and both humeri revealed no abnormalities. A flat plate of the abdomen showed that the liver was normal, the kidneys were normal in size and position, and there was no evidence of opaque calcification. Chest roentgenograms showed the lungs to be clear, with no infiltration or consolidation.

The preoperative diagnosis was primary neoplasm of the left clavicle, probably malignant.

Operation

On August 31, 1944, a biopsy of the mass was done. The sections obtained from this biopsy showed only inflammation and necrosis, suggestive of eosinophilic granuloma, but no evidence of malignancy. In view of these findings, a thorough excision and curettage of the affected area of the left clavicle was

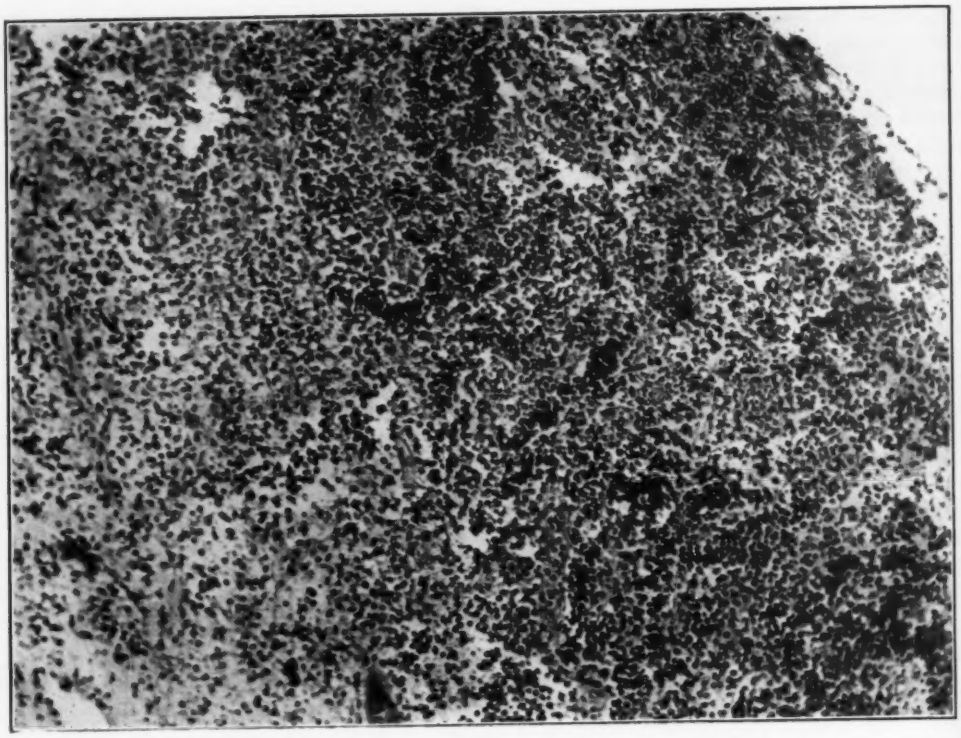

FIG. 2

Microscopic section, low-power field, showing sheets of eosinophils.

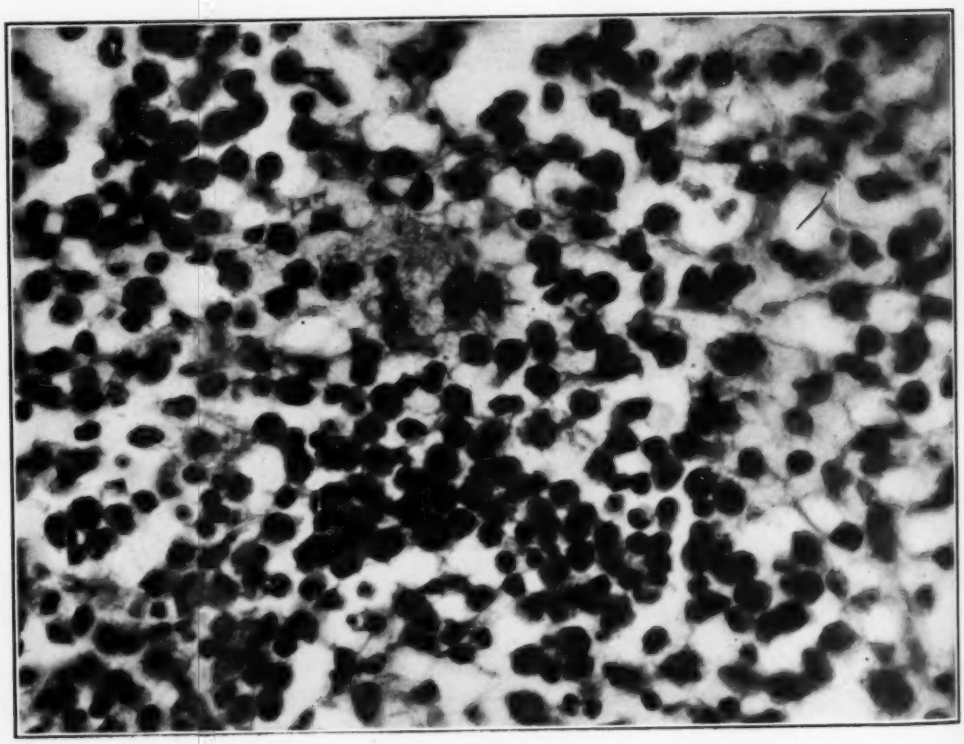

FIG. 3

Microscopic section, high-power field, showing numerous eosinophils and a few large histiocytes.

done on September 2, 1944. At operation, the gross appearance of the lesion was that of a firm, reddish-gray, fleshy mass, approximately 2.5 centimeters in diameter, extending deep into the body of the clavicle. The involved tissue was friable, bled easily, and was not attached to surrounding soft tissue. There was questionable involvement of the attachment of the sternocleidomastoideus in this area, and a portion of the muscle was excised. Bleeding from surrounding bone and soft tissues was moderate. A thorough excision of the mass, curettage of the clavicular defect, and saucerization were done.

Pathological Findings

Gross Appearance: The specimen consisted of numerous fragments of friable, hemorrhagic, grayish-yellow tissue, measuring in aggregate 3 by 2.5 centimeters, and several spicules and small pieces of bone.

Microscopic Appearance (Figs. 2 and 3): Thirteen sections were fixed in a solution of 10 per cent. formalin and stained with hematoxylin and eosin. The sections showed a loose vascular granulation tissue, infiltrated predominantly by eosinophils. These were mainly of the polymorphonuclear variety, although a few mononuclear forms were present. In addition to the eosinophils, there were many large cells with rounded, oval, or reniform nuclei; these were probably histiocytes, although no definite phagocytic activity could be made out. The histiocytes were occasionally multinucleated. In some sections the histiocytes were present in large sheets and were the predominating cell form. In addition to the eosinophils and the histiocytes, a small number of scattered lymphocytes and polymorphonuclear neutrophils were present. A striking feature of many of the sections was the large areas of hemorrhage, degeneration, and necrosis. In several places reparative fibrosis was noted. Small pieces of bone were present in several sections. The marrow spaces were replaced by a loose fibrous tissue, permeated by a few eosinophils and small round cells. There appeared to be a formation of poorly calcified new bone in several places. One section showed a marked proliferation of fibroblasts, with an associated formation of osteoid tissue.

Cultures taken from the site of the lesion and grown aerobically and anaerobically were sterile.

The diagnosis was eosinophilic granuloma of bone.

Progress

The patient withstood the operative procedure well, and the postoperative course was uneventful. Skin sutures were removed on the seventh day after operation; although there was still tenderness in the region of the wound, this was considerably less marked than before operation. There was no evidence of recurrence of the mass, and no drainage from the wound. Roentgenograms of the clavicle showed some filling in of the bone defect within a month after operation. The patient had normal shoulder motion, without pain. In a final roentgenogram of the clavicle, a faint elliptical translucent area was noted in the shaft of the third rib posteriorly. This finding was thought to represent another possible focus of eosinophilic granuloma of bone, and roentgenotherapy was considered to be the procedure of choice. This lesion produced no symptoms and the patient was completely free of symptoms referable to the clavicle. Since this Hospital was not authorized to give roentgenotherapy, the patient was transferred to the Walter Reed General Hospital, Washington, D. C. The roentgenographic consultant at Walter Reed General Hospital did not believe that the findings in the left posterior rib were indicative of another focus of eosinophilic granuloma, nor did he feel that roentgenotherapy was indicated so far as the clavicular lesion was concerned. Therefore the patient was discharged from the Hospital on October 31, 1944, to full military duty, to continue his work as an aviation cadet.

In a personal communication on December 26, 1944, the patient stated that he weighed 144 pounds, that his clavicle "felt fine", and that he had had no pain or recurrence of the swelling. He was carrying on full-time in the ground training program for aviation cadets, without complaint or symptoms referable to his musculoskeletal system.

COMMENT

The clinical and roentgenographic picture presented by eosinophilic granuloma of bone is not specific, and may mimic a variety of inflammatory and neoplastic processes. Thus, in the case reported, the original diagnosis was acute osteomyelitis and the preoperative diagnosis a malignant bone tumor. If the lesion is solitary, it may be confused with giant-cell tumor of bone, bone cyst, or even Ewing's tumor. Often osteomyelitis, tuberculosis, or syphilis enter into the differential diagnosis. If the lesions are multiple, they may bear a striking resemblance to multiple myeloma; the osseous lesions of lymphoma; or metastases from malignant tumors, such as neuroblastoma. The differentiation is often impossible on clinical, roentgenographic, or laboratory evidence, and will depend upon histological examination.

Eosinophilic granuloma of bone is considered by Jaffe and Lichtenstein and by Green

and Farber to be a variant of Hand-Schüller-Christian disease and Letterer-Siwe disease. Both these conditions are markedly different clinically from eosinophilic granuloma, but the histological pictures bear striking resemblances to each other and transition stages between the three diseases have been reported.

Letterer-Siwe disease occurs in young children, usually below the age of two, and in most cases runs a rapidly fatal course. It is characterized by fever, anaemia, hepatosplenomegaly, generalized lymphadenopathy, purpura, and multiple bone lesions. Histologically, there are focal or diffuse collections of histiocytes in the visceral and bone lesions, with an occasional sprinkling of eosinophils. The early lesions may be indistinguishable from eosinophilic granuloma of bone, and the older lesions may show evidence of fibrosis and the transformation of the histiocytes into lipophages.

Hand-Schüller-Christian disease occurs in older children, or occasionally in adults, and runs a milder and much more chronic course. It is characterized by the presence of lipogranulomatous foci in various viscera and bones. The classical triad of skull defects, exophthalmos, and diabetes insipidus results from involvement of the skull, although other organs and bones may be involved and the clinical picture may vary accordingly. In some cases it is possible to demonstrate the existence of focal collections of histiocytes and even eosinophils. It is believed by Jaffe and Farber that these gradually undergo fibrosis and the histiocytes are transformed into foam cells or lipophages, to produce the microscopic picture which is associated with Hand-Schüller-Christian disease.

The relationship of the three diseases is well summarized by Mallory: "Strongly suggestive evidence therefore lies at hand that all these various syndromes represent a single disease entity—rapidly fatal in the infantile forms, which have been described as Letterer-Siwe's disease and reticuloendotheliosis; chronic, but still of serious import because of the likelihood of cerebral and hypophyseal involvement, in early childhood (Hand-Schüller-Christian's disease); and comparatively benign in later childhood or in the adult, where the usual picture is that of eosinophilic granuloma. Proof of this identity must of course await the discovery of the etiology."

REFERENCES

Farber, S.: The Nature of "Solitary or Eosinophilic Granuloma" of Bone. Scientific Proc., Am. J. Pathol., **17**: 625–629, 1941.

Green, W. T., and Farber, S.: "Eosinophilic or Solitary Granuloma" of Bone. J. Bone and Joint Surg., **24**: 499–526, July 1942.

Greenberg, B. B., and Schein, A. J.: Solitary Eosinophilic Granuloma of Bone. Am. J. Surg., **67**: 547–555, 1945.

Jaffe, H. L., and Lichtenstein, L.: Eosinophilic Granuloma of Bone. A Condition Affecting One, Several or Many Bones, but Apparently Limited to the Skeleton, and Representing the Mildest Clinical Expression of the Peculiar Inflammatory Histiocytosis Also Underlying Letterer-Siwe Disease and Schüller-Christian Disease. Arch. Pathol., **37**: 99–118, 1944.

Lichtenstein, L., and Jaffe, H. L.: Eosinophilic Granuloma of Bone. With Report of a Case. Am. J. Pathol., **16**: 595–604, 1940.

Mallory, T. B.: Pathology: Diseases of Bone. New England J. Med., **227**: 955–960, 1942.

Otani, S., and Ehrlich, J. C.: Solitary Granuloma of Bone. Simulating Primary Neoplasm. Am. J. Pathol., **16**: 479–490, 1940.

DEFORMITY OF THE RADIUS PRODUCED BY AN ANEURYSM

Report of a Case

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Injuries sustained during World War II have been manifested in many ways. The following case report describes a type of injury which, to our knowledge, has not previously been reported.

CASE REPORT

N. I., a soldier, twenty-one years of age, was wounded through the right forearm by machine-gun fire on February 2, 1945. He was taken prisoner, and given first-aid treatment in an enemy Aid Station. The following day he was recaptured by American troops and, after débridement of the wound, the extremity was encased in plaster. Roentgenographic examination, twenty-four hours after injury, revealed lateral displacement of the fragments of the radius (Fig. 1). On February 22 secondary closure of the wounds was performed, and the plaster cast was changed. On March 7 the cast was again changed, and traction was applied through the thumb for correction of the lateral displacement of the comminuted fragments of the radius.

Upon admission to Ashford General Hospital on April 13, 1945, the plaster cast and the thumb traction were removed. Physical examination showed a healed wound of entrance on the ulnar aspect of the lower third of the right forearm, and a healed wound of exit on the radial aspect of the upper third of the right forearm. Flexion of the right index finger was limited, with complete loss of pronation and supination of the right forearm. Palpation revealed a firm, non-tender swelling over the region of the mid-portion of the radius. Hypaesthesia was present along the distribution of the superficial radial

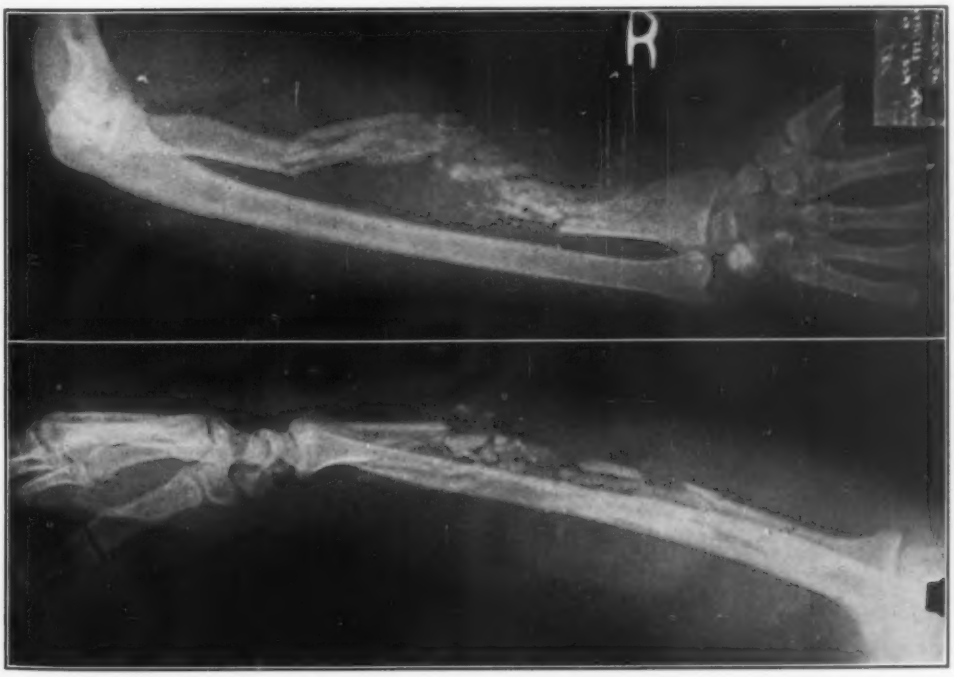


Fig. 1

Roentgenograms of the right forearm, twenty-four hours after injury. The fragments describe an even arc.

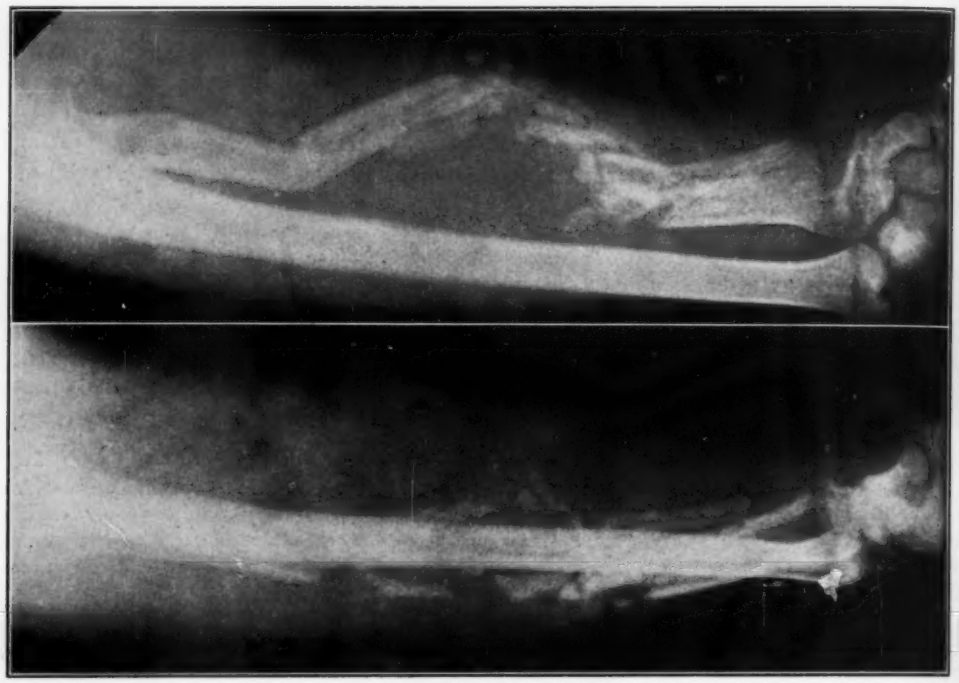


FIG. 2

Preoperative roentgenograms, taken eleven weeks after injury, show no essential change from Fig. 1.

nerve. Elbow motion was normal. Roentgenographic examination (Fig. 2) revealed the same deformity which had been noted twenty-four hours after injury. It was decided that the deformity of the radius should be excised, and the defect bridged with a tibial graft.

On May 29, 1945, with a pneumatic tourniquet in place on the arm, an incision was made between the extensor carpi radialis brevis and the extensor digitorum communis. As the periosteum was incised and stripped from the radius, a large amount of organized clot was seen. Evacuation of the clot revealed a false aneurysmal sac between the radius and ulna, measuring approximately 5 centimeters in diameter (Figs. 3-A and 3-B). The tourniquet was released temporarily, and blood spurted from a small opening in the volar surface of the interosseous artery (Figs. 4 and 5). The artery was ligated proximal and distal to the opening with No. 40 cotton suture, and the false sac was excised. The comminuted

FIG. 3-A

FIG. 3-B

Fig. 3-A: False sac of aneurysm with clot evacuated (on gauze).
Fig. 3-B: Cavity produced by false aneurysm.

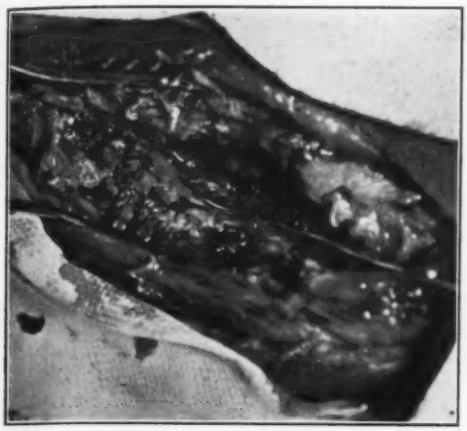


FIG. 4

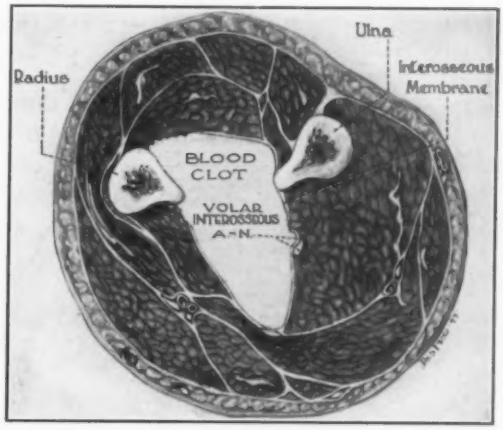


FIG. 5

Fig. 4: Probe inserted through opening in volar surface of the interosseous artery.

Fig. 5: Schematic cross section of the forearm at site of aneurysm, showing displacement of artery and nerve.

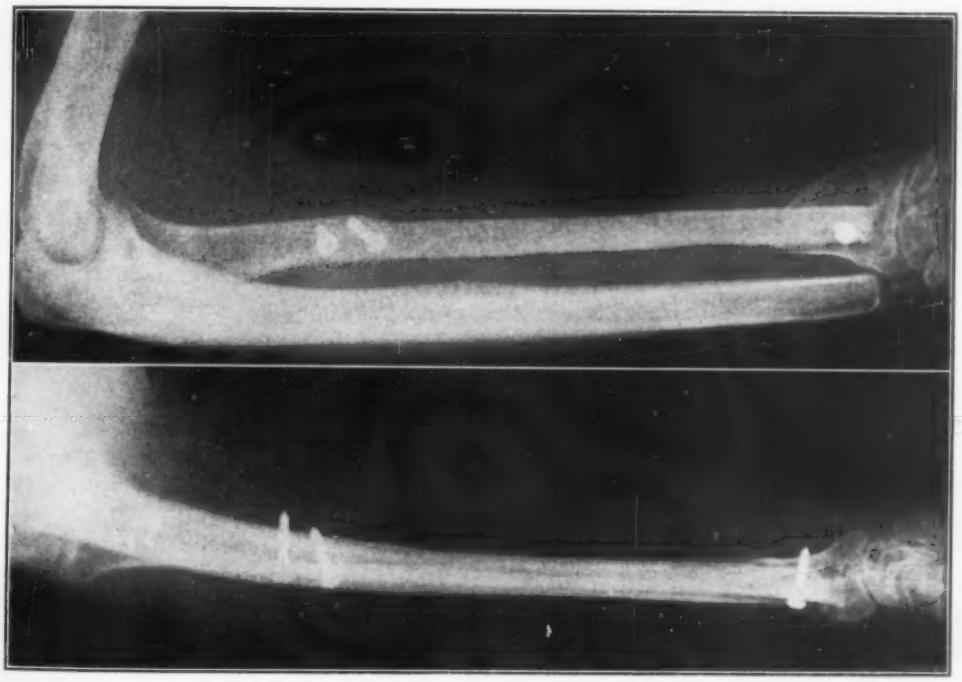


FIG. 6

Roentgenograms show radial graft, four months after operation.

portion of the radius was excised; and the 11 centimeter gap was bridged by a tibial graft, measuring 13 by 1.5 centimeters. The graft was fixed with two stainless-steel screws in the proximal end, and one screw in the distal end. The distal end of the ulna was excised to accomplish alignment of the radial fragments, and to correct radial deviation of the hand. The tourniquet was removed, and the wound was closed in layers, with interrupted cotton sutures. The extremity was encased in plaster, with the elbow in 90 degrees of flexion and the forearm midway between pronation and supination.

The postoperative course was uneventful. Four months after operation there was clinical union of the radius, with satisfactory roentgenographic appearance (Fig. 6). Six months after operation supination was complete, and pronation was 60 per cent. of normal.

SUMMARY AND CONCLUSIONS

The presence of this aneurysm, which produced uniform deformity of the radius, w not suspected prior to operation. From the case, the following conclusions may be draw

1. Uniform deformity of a comminuted bone should make one suspect the presen of an aneurysm.
2. The deformity achieves maximum size almost immediately after injury.
3. The two lesions may be corrected successfully at the same time.

CALCAREOUS TENDINITIS OF A FLEXOR TENDON OF THE FINGER

Report of a Case

BY LIEUTENANT COLONEL JOHN R. VASKO

Medical Corps, Army of the United States

Amorphous calcification occurs in various tendinous tissues of the body, the usua sites being the capsule of the shoulder joint, about the insertion of the supraspinatus ten don; the capsules of the finger joints; the tendo calcaneus; and the capsule of the kne joint. The purpose of this article is to report another site of calcification, — that of a flexor tendon of a finger.

The etiology for calcification of tendinocapsular tissues is still in doubt. Some writ ers [1,2,3] believe that trauma is the cause, others [4] that it is a metabolic disturbance or tha it is due to a deficiency of vitamin E. It has also been pointed out that necrosis of tissue with subsequent calcification, may occur. In the case being reported here there was no history of recent trauma, although minimum injuries, such as are frequent in everyday life, may have occurred and been forgotten.

The treatment of these cases of calcification varies from no therapy to surgical re moval, and includes physiotherapy, salicylates, roentgenotherapy, needling, irrigation novocain injection, aspiration, and the administration of vitamin E. Obviously no specific therapy is effective in every case, and some of these calcifications—especially those abou the shoulder—are notoriously resistant to all forms of therapy. Sutro and Cohen have ob served that the calcareous deposits sometimes disappear spontaneously, without treatment. In the case to be discussed, rest alone sufficed.

CASE REPORT

E. B. H., a white male, aged twenty-eight, entered the hospital on August 12, 1944, with the com plaint that his right middle finger was swollen and painful on the volar surface. The onset was gradual

FIG. 1

FIG. 2

Fig. 1: Shows calcification within the flexor tendon on August 14, 1944, before treatment was begun.
Fig. 2: Shows the calcification two weeks later, after treatment was begun.

and had begun three or four weeks before. The patient remembered no recent injury to the finger, and, since he was an office worker, minor injuries due to his occupation were unlikely. He stated that in 1935 he had injured the finger while playing football, but had had no trouble with it until recently. No other joints were affected. The past history was unremarkable. The patient's chief complaints were pain, swelling, and limitation of motion of the distal interphalangeal joint of the right middle finger.

The physical examination was negative, except for some caries of the teeth and for the right middle finger. This finger was moderately swollen about the middle phalanx on the volar aspect; it was tender, and there was limitation of motion of the distal interphalangeal joint. There was no redness, [illegible] athy, or fever.

The roentgenographic report was as follows: "X-ray of the right hand reveals that there is a saucer-shaped area of ossification, measuring 15 millimeters in length, 7 millimeters in breadth, and 5 millimeters in thickness, lying in the soft tissues anterior and proximal to the distal interphalangeal joint. There is also a spur from the anterior margin of the joint surface of the distal phalanx. These changes are probably posttraumatic, and probably related to such pathological changes as a tendinitis or myositis ossificans."

The blood findings were as follows:

Red blood cells	4,440,000
Hemoglobin	90 per cent.
White blood cells	5,950
Polymorphonuclear neutrophils	60 per cent.
Lymphocytes	35 per cent.
Eosinophils	5 per cent.

The urine was yellow and hazy, and gave an acid reaction; the specific gravity was 1.026; tests for albumin and sugar were negative.

The tentative diagnosis was calcification of the deep flexor tendon, the tendon sheath, or both.

Progress Notes

On August 14 the diagnosis was still uncertain, but there appeared to be calcification of the tendon at its distal end, near its insertion near the spur on the volar surface of the base of the distal phalanx (Fig. 1). On August 16 surgical intervention was planned, and an aluminum finger splint was applied to the flexed finger. By August 21 the swelling and inflammation had subsided considerably. A furuncle had developed on the wrist, and surgery to the finger was postponed. The carbuncle was opened on August 22, and a dressing was applied. Dry heat, three times a day, was advised. By August 29 the carbuncle had practically healed, and no drainage was present. The finger was no longer swollen or

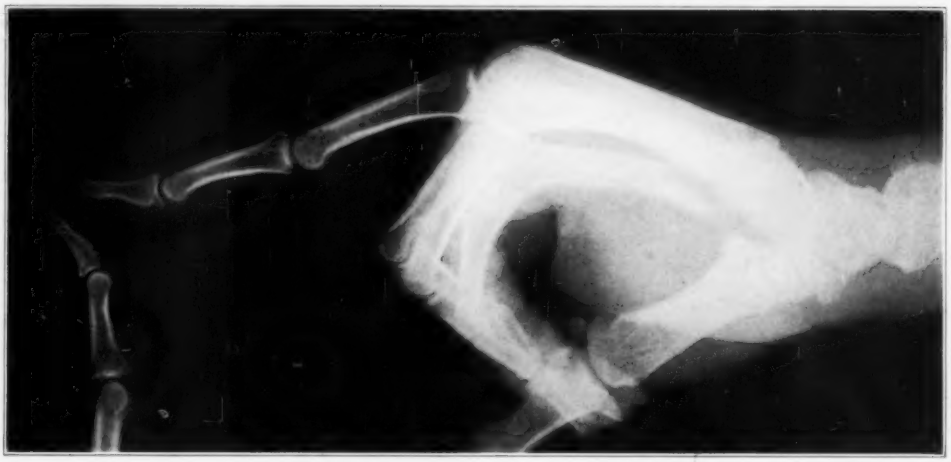


FIG. 3

Four months later, hardly any trace of the calcium remains.

painful. Roentgenograms showed a disappearance of the calcification (Fig. 2). The patient was to be discharged to duty. He was to return to the hospital, if necessary, and to be followed in the clinic.

The patient was seen again on January 11, 1945. At that time he had no swelling, pain, or tenderness of the finger, and the function was normal. A small spur could be felt on the flexor surface of the distal phalanx. Roentgenograms (Fig. 3) showed only the faintest trace of the previous calcification. The patient was performing full duty, and had received no treatment to the finger since leaving the hospital, other than continuation of the splint for an additional two weeks.

COMMENT

This patient's injury to his finger while playing football, nine years before, probably caused the spur on the distal phalanx. It is unlikely that this original injury was a factor in producing the calcification, because the patient was free from symptoms until shortly before admission to the hospital. The spur, however, may have been a contributing factor by causing local irritation during joint movement. The rapid disappearance of the calcium deposit, with rest alone, would tend to substantiate the latter hypothesis. Calcareous deposits, however, frequently disappear spontaneously without treatment, which invites speculation. Possibly in these cases a reversible local or general metabolic process is present, which, upon returning to normal, causes the absorption of the deposit. What effect the splint produced in this case, therefore, is uncertain. Until our knowledge of the etiology of these deposits is greater, the rationale of treatment cannot be entirely sound, which suggests that conservative treatment should always be tried first.

REFERENCES

1. BRUMBAUGH, H. L.: Calcifying Tendinitis Traumatica. Diagnosis and Treatment of Post-Traumatic Changes in and About Joints. Am. J. Surg., **48**: 681–684, 1940.
2. COOPER, WILLIAM: Calcareous Tendinitis in the Metacarpophalangeal Region. J. Bone and Joint Surg., **24**: 114–122, Jan. 1942.
3. ROTHBERG, A. S.: Tendinitis Ossificans Traumatica. Am. J. Surg., **58**: 285–288, 1942.
4. SUTRO, C. J., and COHEN, L. J.: Basis and Treatment of Calcification of Tendinocapsular Tissues, Especially the Supraspinatus Tendon. Arch. Surg., **42**: 1065–1071, 1941.

THREE INSTRUMENTS DESIGNED TO FACILITATE THE BANKART OPERATION FOR RECURRENT DISLOCATION OF THE SHOULDER *

BY CAPTAIN R. G. LAMBERT AND COLONEL THOMAS HORWITZ

Medical Corps, Army of the United States

The operation described by Bankart in 1938 for repair of recurrent dislocation of the shoulder is admittedly the only anatomical and physiological operation which has been described for this condition. All other operations provide substitutions and fail to correct the true cause of the disability, in spite of the fact that a high degree of success has been obtained with some of them. Bost and Inman, reporting ten cases of Bankart repair in 1942, fully corroborated Bankart's original contention that the basic pathological process is a tearing away of the glenoidal labrum from the anterior aspect of the glenoid fossa, with or without tearing of the anterior capsule.

In spite of the fact that the aim of the Bankart operation is a simple one—that is, drilling two or three holes in the glenoid lip, passing sutures through the holes, and fixing the glenoidal labrum back in place by tying the sutures over the detached labrum—the procedure is actually fraught with numerous technical difficulties, which probably account for the failures (in a small percentage of

FIG. 1

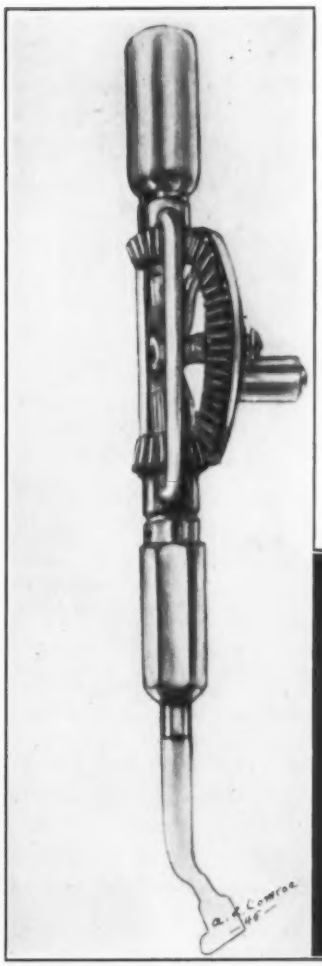


FIG. 2-A

Fig. 1: Curved Y-shaped "pusher" type of retractor for displacing the head of the humerus out of the operative field.

Fig. 2-A: The right-angle drill, constructed by modifying a hand drill to fit the hand piece of a standard dental drill; used for drilling the holes through the lip of the glenoid fossa.

Fig. 2-B: The hand piece of the dental drill, with drill attached.

FIG. 2-B

* Presented at the meeting of the Chicago Orthopaedic Society, Vaughan General Hospital, Hines, Illinois, April 13, 1945.

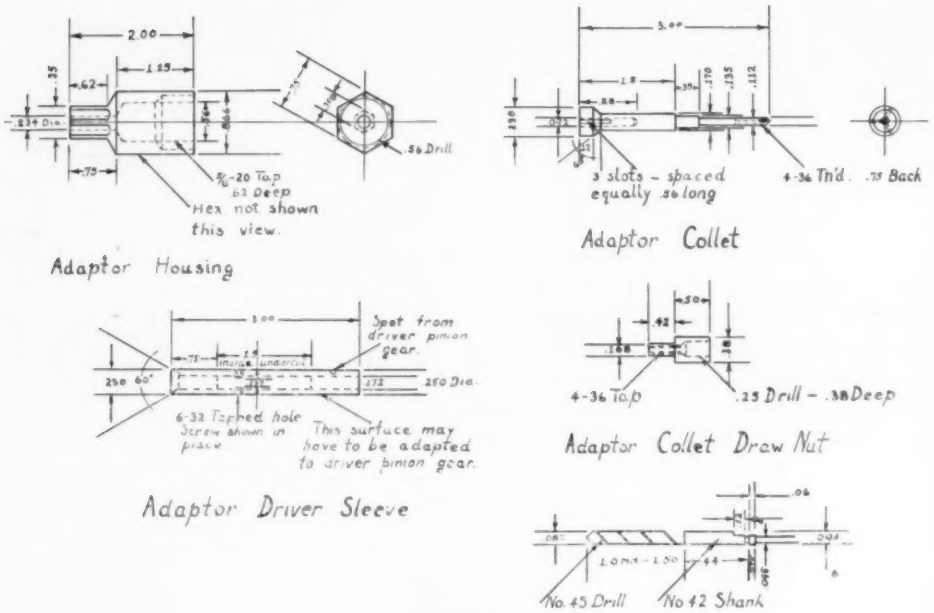


FIG. 3-A

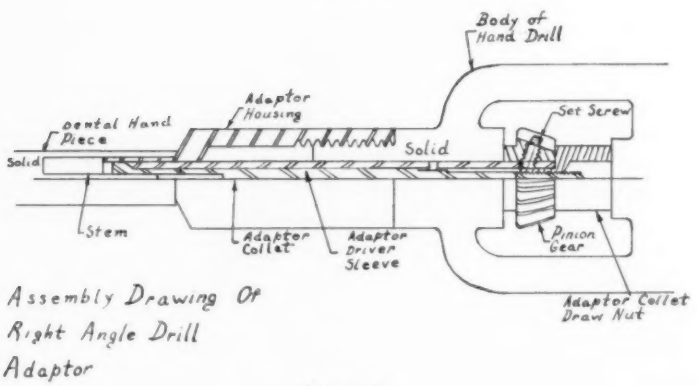


FIG. 3-B

Adaptor Housing: Fits on the end of the drill and serves as an adaptor between the drill and the dental hand piece, which is locked in position by the hexagon at the end of the housing.

Adaptor Driver Sleeve: Fits into the adaptor housing and transmits the actual power from the driver pinion to the adaptor collet; also serves to tighten the collet on sleeve lock in conjunction with the adaptor collet draw nut.

Adaptor Collet: Transmits power to the stem of the dental hand piece.

Adaptor Draw Nut: Acts in conjunction with the adaptor driver sleeve to tighten the adaptor collet on the stem of the dental hand piece.

The Drill: Modification of a standard drill, No. 45, to fit the dental hand piece.

cases) following this procedure. The operation has proved most difficult and trying to surgeons who have attempted its use, and for this reason other methods, such as the Nicola or Henderson operations, have been preferred.

In performing the Bankart operation, three obstacles are at once apparent: The head of the humerus is directly in the operative field, and can be kept out of the way only by the determined efforts of one or more assistants. A straight drill can be introduced into the field only with great difficulty; and, after the holes have been drilled, there is no suitable instrument which will carry the sutures easily through the holes.

Taking these problems in order, three pieces of equipment have been constructed. To facilitate constant displacement of the head of the humerus, a Y-shaped instrument was devised (Fig. 1), which is placed with the Y portion about the neck of the humerus, just

below the capsule. An assistant on the opposite side of the operating table, by pressure on the handle, easily displaces the head of the humerus posteriorly and laterally, giving exposure of the entire glenoid fossa.

The most difficult problem—that of constructing the drill holes—was solved by developing a right-angle drill. A few modifications were made in an ordinary mechanic's drill, and a standard dental drill tip was attached (Fig. 2-B). The result is an instrument which expedites the construction of the drill holes in the glenoid lip. Even though this drill tip is small enough to be inserted between the head of the humerus and the glenoid, it has been found easier to work from the medial side of the scapula and to drill toward the joint. Drill points are fastened into the dental tip by a snap lock, and, by being made flat on one side, they mesh with the driving mechanism. These drill points may easily be constructed from a standard drill, size No. 45 (Fig. 3-A).

The difficulty of passing the sutures through the holes was met by devising a right-angle suture carrier of a size to fit the drill holes. The tip of the carrier has a small hook, which catches the heavy braided silk suture and delivers it through the drill hole (Fig. 4).

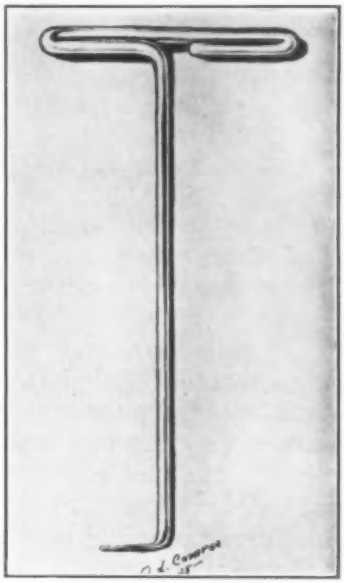


FIG. 4

The right-angle suture carrier, made of a size to fit the drill holes, with a small hook on the end to catch and deliver the suture through the holes.

These three pieces of equipment are simple enough of design to be made by any qualified mechanic or brace maker; and, including the dental drill tip, they cost less than $15.00.

In eight patients operated upon by the authors, the equipment just described has been used; and it has proved invaluable in facilitating a most difficult and tedious operation. On first using these tools in two cases, the authors have reduced the operating time to one hour and forty minutes and one hour and thirty minutes, respectively, from skin incision to dressing. It should not be assumed from this that the operation has been made simple in all cases. Each author has encountered a case in which, for some unknown reason, the head of the humerus could not be displaced out of the field, and the operation was consequently difficult. It is felt, however, that, without the tools described, the Bankart operation could not have been carried out in these two cases.

The pathological findings in each case have sustained Bankart's contention as to the basic lesion in recurrent dislocation of the shoulder. Since the eight patients have all been operated upon within the past five months, no end results are presented, although there have been no recurrences to date. It is not the purpose of the authors to discuss the relative merits of the Bankart operation; but they feel that the correction of the fundamental pathological process in any lesion, when possible, offers the most certain promise for physiological recovery.

REFERENCES

BANKART, A. S. B.: The Pathology and Treatment of Recurrent Dislocation of the Shoulder-Joint. British J. Surg., **26**: 23–29, 1938–39.

BOST, F. C., AND INMAN, V. T.: The Pathological Changes in Recurrent Dislocation of the Shoulder. A Report of Bankart's Operative Procedure. J. Bone and Joint Surg., **24**: 595–613, July 1942.

RUPTURE OF THE PECTORALIS MAJOR

Report of a Case

BY DANIEL M. KINGSLEY, M.D., NEW ORLEANS, LOUISIANA

Reports of rupture of the pectoralis major are rare. Pulaski and Chandlee summarized the literature on seventeen patients with this lesion, and included one case of their own. A nineteenth patient was described by Parkes. The present paper adds the report of another case.

It would seem, however, that the condition is not so rare as the literature might lead one to conclude. Pulaski and Chandlee mention the statement of Saar, Bernhard, and others that "the injury is not uncommon in sports but is infrequently diagnosed". Bunnell mentions these ruptures, and describes their repair. The paucity of reported cases probably is due to the fact that any one surgeon usually encounters only a solitary instance and does not consider it worth reporting.

Rupture of any of the larger muscles is seen infrequently. For example, review of all available record files at Charity Hospital of Louisiana in New Orleans, with admissions in some years ranging as high as 69,229, fails to reveal a single instance of rupture of the pectoralis major. Indeed, the diagnosis of rupture of any muscle was infrequent. In a year's work as orthopaedic surgeon for an infantry camp which had a total population (including turnover) of about 65,000 men, engaged in training of a violent and urgent character, the author encountered only three tears of large muscles or tendons, as follows: one each of the supraspinatus, the quadriceps femoris, and the tendo calcaneus. It should be noted that all of these injuries occurred in extremities.

Pulaski and Chandlee summarized the etioloy of the recorded tears of the pectoralis major, as follows:

Group 1.	Due to senile changes	2
Group 2.	Due to direct violence	1
Group 3.	Due to strong pull on the contracted muscle	10
Group 4.	Combination of direct blows and violent pull	5

Parkes's case comes under Group 3.

The following case history falls into the category of rupture due to a strong pull on a normal, contracted muscle.

CASE REPORT

History

A white male, aged twenty-six, with powerfully developed muscles, had been a nationally known football player in college. After graduation, he was employed as an engineer. In the course of his work, he entered a deep hole, bordered by a concrete wall. On attempting to climb out, he grasped the edge of the wall some distance above his head. His right forearm was on top of the wall, and his fingers had a good grasp of the far edge. Most of his weight (195 pounds) was suspended from his right upper extremity. His left arm was helping to lift him by pushing from below. Because of the small diameter of the hole, he could not use both arms to equal advantage. Therefore, not much force was being exerted by the left upper extremity.

As he tensed the muscles of his right upper extremity in attempting to lift himself, the patient felt a sudden, severe, tearing and burning pain in the area of the right chest, anteriorly. The upper extremity on this side immediately became totally disabled, but he managed to get out of the hole.

Pain prevented the patient from using the right arm for about two weeks. There was no other area of pain, and the shoulder joint was normal. Any motion which stretched the right pectoralis major could not be performed, because of pain. Hemorrhage was noticed immediately after the injury. It began in the area of the right anterior axillary wall, but soon extended down the anterior chest wall to the region of the upper abdomen. It resulted in marked subcutaneous color changes, which persisted for a period of three weeks.

Because of the inability to use his arm, the patient consulted a surgeon, who correctly diagnosed the condition and advised suture of the muscle. The patient refused operation, however, and the only treatment consisted of application of a Velpeau type of bandage. Gradually, over a period of a month, strength returned in large measure; but the patient has been aware of the fact that, since his injury, his right arm has not been quite so strong as it had been previously. He stated, however, that he has always considered his residual disability as inconsequential.

Physical Examination

Eight years after the original injury, examination was performed for a minor condition not related to the muscle. The muscle injury was discovered during the course of the general examination. The patient had large bones and powerful muscles, but had not kept up his former athletic training. In the course of appropriate functional tests, the only abnormality which could be found was that muscle strength of the right pectoralis major was slightly, but definitely, decreased by comparison with the corresponding muscle of the intact left side. There was moderate flattening of the right pectoral area, most conspicuous at the deltopectoral junction. The flattening was not marked when the arms were at the sides, but was easily apparent when the arms were held in partial abduction, especially when resistance was exerted. The anterior axillary fold was more nearly vertical on the injured side than on the normal left side, so that the axilla itself was more shallow on the right.

On palpation, the right anterior axillary fold was decreased in thickness about 50 per cent. more than that on the left side. In the anterior axillary wall, the entire thickness of the sternocostal portion of the pectoralis major was absent in a longitudinal area corresponding to the junction of the muscular and tendinous portions. Here a thin scar, about three centimeters long, connected the mid-portion of the tendon to the atrophied sternocostal portion of the muscle which remained. The sternocostal portion of the muscle was functioning, but it was decreased about 75 per cent. in mass. The clavicular portion showed only a trace of decrease in mass, and the abdominal portion was slightly decreased. Across the area of the tear in the muscle was a skin crease, where the skin had become slightly adherent to the scar underneath.

The slight degree of functional impairment in this case seems to be due to two factors: first, the transmission of muscle power through the scar to the tendon; and second, the minor role of the sternocostal portion of the muscle in the ordinary use of the arm, as has been shown by Inman, Saunders, and Abbott.

REFERENCES

Bunnell, Sterling: Surgery of the Hand, p. 431. Philadelphia, J. P. Lippincott Co., 1944.

Inman, V. T.; Saunders, J. B. de C. M.; and Abbott, L. C.: Observations on the Function of the Shoulder Joint. J. Bone and Joint Surg., **26**: 1–30, Jan. 1944.

Parkes, M.: Rupture of the Pectoralis Major Muscle. Industrial Med., **12**: 226, 1943.

Pulaski, E. J., and Chandlee, B. H.: Ruptures of the Pectoralis Major Muscle. Surgery, **10**: 309–312, 1941.

CONCEALED CYSTS OF THE LATERAL MENISCUS OF THE KNEE

Report of a Case

BY R. J. DITTRICH, M.D., DULUTH, MINNESOTA

Cysts of the menisci are not uncommon, although only in recent years have they received much attention. They are found most frequently in the lateral meniscus. The diagnosis is, as a rule, not difficult, as the cysts occur almost invariably at the outer margin of the meniscus, and thus are palpable or visible at the time of examination.

Ollerenshaw reported in 1935 that he had treated forty-two cases, of which thirty-six occurred in the lateral meniscus and six in the medial meniscus. Among these was "one case in which the cyst arose from the free border of the external cartilage and projected towards the middle of the joint, lying against the crucial ligaments". This was found in a girl, eleven years old, who gave a history of a sprain of the knee at six years of age, and subsequently had occasional attacks of stiffness and locking. The operative approach was made through a mid-line incision, splitting the patella. "On retraction a cystic swelling, the size of a cherry, was found to be attached to the free (medial) edge of the outer semilunar cartilage and lying closely against the crucial ligaments. The cartilage was an unusually broad one. It was excised completely with the cyst."

In a survey of 110 publications on this subject, Sjövall reviewed 358 cases, including twelve of his own. He discussed at great length the etiological, pathological, and therapeutic aspects of this condition. In this material he was able to find only one case of concealed cyst,—that reported by Ollerenshaw.

CASE REPORT

The patient seen by the author was a male, aged thirty-two, who was employed as a shipfitter's helper. He was seen about two hours after he had slipped on the deck of a ship, twisting his left knee. This accident was followed by intense pain and mild swelling; and the knee was held in a position of slight flexion, from which it could not be completely straightened.

The man stated that four years before, while working on a farm, he had had a similar, although less severe, injury to the same knee. At that time he had moderate pain, with no restriction of motion. He had recovered in about one week, and since then he had occasionally had slight pain. He stated that he had been rejected for military service, owing to this knee condition.

Examination showed that the patient had a moderate limp on the left, and in walking the knee was flexed to about 30 degrees. Active motion in the left knee was present from 90 to 150 degrees; passive extension was obtained up to 170 degrees. On active and passive motion, pain was produced on the anterolateral aspect of the knee joint. No effusion was noted, but a mild puffiness spread anterolaterally over the joint space, and in this area there also was definite tenderness. No abnormal anteroposterior or anterolateral mobility was noted, and no pain was produced on attempts to rotate the leg. There was no point of tenderness elsewhere about the knee joint.

Roentgenographic examination, including anteroposterior and lateral views of the left knee, showed no abnormality.

The man was seen two days later, at which time his knee had become somewhat more painful. There was little or no change in the objective findings from those noted previously. A diagnosis was made of rupture of the left lateral meniscus, and it was considered advisable to undertake an exploratory operation of the joint.

Operation, four days after the injury, consisted of an incision lateral to the patella, with a longitudinal incision through the joint capsule. About 10 or 15 cubic centimeters of viscous, straw-colored fluid escaped from the joint. After the joint capsule had been opened, the anterior portion of the lateral meniscus was found to be detached and hypermobile; near the anterior pole of the lateral meniscus a small swelling was found, which had the appearance of a cyst. This was about one centimeter in diameter, and arose from the superior surface of the anterior portion of the meniscus. A similar cyst, about five by two by two millimeters in size, was found to arise from this area and to be separated from the larger swelling by about two or three millimeters. The meniscus was freed from its attachments and removed as far posteriorly as possible; the posterior portion was left intact. The incision was closed in layers.

The postoperative course was favorable, with the exception of a small hematoma, which developed in the subcutaneous tissue; this was evacuated several days after the operation.

The man returned to his former work seven weeks after the operation. He was seen again about three months after the operation, at which time he stated that he had been working regularly. He had no complaints of pain or other disability. Motion in the knee was present from 75 to 180 degrees; there was no tenderness or effusion, and power of the knee in extension and flexion was estimated at 80 per cent. of normal.

The pathologist's report, limited to a description of the larger cyst, is as follows: "Macroscopically, the specimen consists of a cyst one centimeter in diameter, with rather thick walls (two millimeters) and smooth inner surface. The cyst is attached, over an area of about one centimeter in diameter, to a base of fibrocartilage. Microscopically, the cyst has thick, fibrous walls with few cells. The nuclei are small and the interstitial tissue is extensively hyalinized. The cyst is lined with a synovial-like membrane, with flattened cells. There is no inflammatory or neoplastic type of proliferation or infiltration."

COMMENT

This case is of interest for the reason that cysts arising from this location are evidently very rare. There is no certain way of determining the time of origin of the tumors in this case, and it is questionable whether they were the cause of any part of the patient's complaints. It seemed at the time of the operation that the detachment of the meniscus was probably the cause of the man's disability. From the location of the cysts near the anterior pole of the meniscus, it is probable that during motion there was no serious disturbance, as the tumors probably receded into the intercondylar space, and in this manner escaped compression by the lateral condyle in full extension.

REFERENCES

OLLERENSHAW, ROBERT: A Further Note on the Development of Cysts in Connection with the Semilunar Cartilages of the Knee-Joint. British J. Surg., **23**: 277–279, 1935–36.

SJÖVALL, HELGE: Über Meniscusganglien. Acta Chir. Scandinavica, **87**: 561–583, 1942.

FOOT EXERCISER

BY CHARLES F. SCHROEDER, M.D., EVANSTON, ILLINOIS

The foot exerciser described herein was designed to meet the need for some device for the bedridden patient which would provide easily regulated resistance to both dorsal and plantar flexion of the foot. The exerciser fills these requirements in that it permits adequate control over the amount of resistance to flexion, the range of foot motion, and the duration of active motion. It was intended primarily for the patient with a leg fracture, but it may be used for any condition where active resistive foot motion is indicated.

Figures 1 and 2 illustrate the way in which resistance to dorsal and plantar flexion is created. The exerciser is shown, viewed from the side, mounted on a Thomas leg splint. The exerciser is placed on the frame of the Thomas splint, with the base piece of the exerciser above the frame and the flat metal bar of the clamp attachment below.

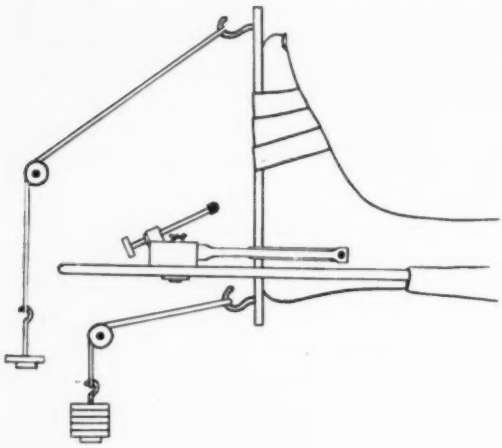


FIG. 1

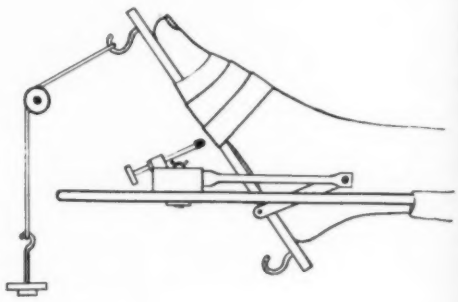


FIG. 2

Fig. 1: *Resistance to Plantar Flexion:* In order to obtain plantar flexion of the foot, the patient must overcome the pull of the lower set of weights.

Fig. 2: *Resistance to Dorsal Flexion:* The lower rope has been removed from the bottom hook of the foot piece. In order to obtain dorsiflexion of the foot, the patient must overcome the pull of the remaining set of weights.

The exerciser is then moved on the frame until the patient's foot and the foot piece are closely approximated. There it is immobilized by tightening the two wing nuts of the clamp attachment. The patient's foot is then secured to the foot piece with an elastic-type bandage. (Movement of the foot is prevented by adjusting the stop to hold the foot piece in the upright position.) When active motion is desired, the stop (shown in Figure 3) is first unscrewed until only a few degrees of flexion are possible. The threaded rod of the stop can be set at any desired position, and therefore the range of foot flexion can be rigidly controlled. The active motion may be free if no weights are attached to the foot piece.

When active resistive motion is desired, the two ropes, which support weights, are attached to their respective hooks, as illustrated in Figure 1. The individual needs of each patient may easily be met by regulating the range of foot motion, adjusting the amount of weight used for resistance, and prescribing the duration of active motion. In the case of a fracture, the three factors are increased within the limits of pain, muscle spasm, and safety to the healing bone. When the patient can tolerate unlimited activity, the stop is unscrewed until it no longer interferes with foot flexion. In the early stages of the fracture, it is advisable not to exercise the foot against resistance to plantar flexion. The counter-

pressure against the base of the foot, transmitted axially, may tend to disrupt the continuity of the fracture.

The possibility of development of foot drop is very unlikely, because the patient exercises his foot against resistance to dorsal flexion; and whenever the patient relaxes his foot, it is automatically pushed into the upright position. This is done automatically because the weight pull for resistance to plantar flexion is sufficient, against the counterpull of the other set of weights, to maintain the foot upright. The foot may be kept upright by setting the stop.

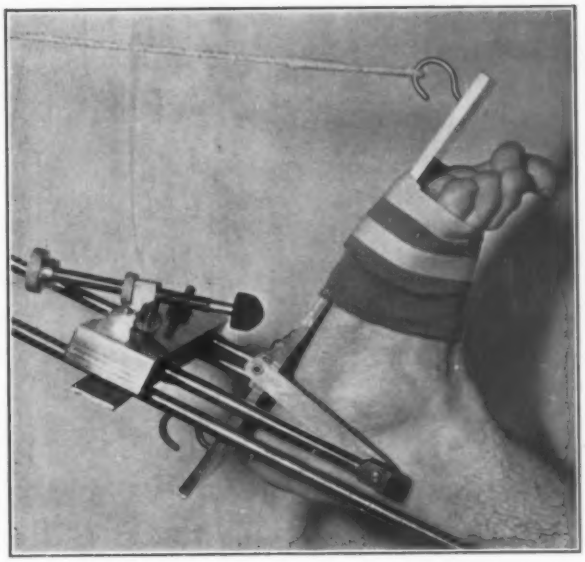


FIG. 3

The stop can be seen on top of the base piece. The wing nuts of the clamp attachment are on either side of the threaded rod of the stop. The main hinge of the foot piece coincides with the axis of the ankle joint.

The exerciser may be used on plaster-of-Paris casts. The part of the cast covering the patient's foot, ankle, and tendo calcaneus may be removed. A Pearson attachment or small Thomas splint is then incorporated, with plaster bandages on the cast. The frame of the splint should be parallel to the leg and one-half inch below the center of the ankle. The exerciser is then mounted and used on the frame, as has been previously described. The Pearson attachment can be incorporated in the cast when it is first applied, if foot, ankle, and tendo calcaneus are not covered. The motion of the foot, including lateral motion, is well restricted by immobilizing the foot piece with the stop, and securely bandaging the patient's foot to the foot piece.

The exerciser is also capable of producing powerful dorsal flexion of the foot, and can therefore be used in the conservative treatment of a shortened tendo calcaneus. The patient's leg is first immobilized by placing it in a cast or in a Thomas splint. If a Thomas splint is used, it is necessary to use countertraction to the skin to maintain the close approximation of the patient's foot to the foot piece. In order to create dorsal flexion, the upper rope pulls in the opposite direction from the lower one; and the pull of both weights combines to produce a powerful, easily regulated dorsal flexion.

SAMUEL FOSDICK JONES
1874–1946

S. Fosdick Jones, known to his host of friends affectionately as "Dick", died March 24, 1946, in Los Angeles. Born in Cincinnati, Ohio, August 4, 1874, he attended Hill School at Pottstown, Pennsylvania, Massachusetts Institute of Technology, and, finally, the College of Physicians and Surgeons (Columbia), New York, where he was graduated in 1902. His professional career started in New York as an intern at the Presbyterian Hospital, The New York Foundling Home, and the Hospital for Ruptured and Crippled. In the latter institution, while working under Dr. Virgil P. Gibney, he became interested in orthopaedic surgery. This association developed into a lifelong and unusually close friendship, and Dr. Gibney's picture always had a prominent place among the many photographs in Dr. Jones's library.

Because of his health, he was sent to California; after a rest of about a year in Pasadena, he went to Denver, where he started in practice in 1906. This city always had a warm spot in his heart for, as he said: "It gave me my health, my practice, and my wife". In 1910 he was married to Mary Catherine Cordes.

For twenty-four years in Denver, he was active in the practice and teaching of his specialty; he was Professor of Orthopaedic Surgery at the University of Colorado School of Medicine, and at the time of his death was Professor Emeritus. In 1930 he had to retire on account of poor health. His last years were spent in Pasadena, California.

In addition to membership in The American Orthopaedic Association, of which he was at one time Vice-President, Dr. Jones belonged to the Western Surgical Association, Clinical and Pathological Society of New York, The American Academy of Orthopaedic Surgeons, American Medical Association, and American College of Surgeons.

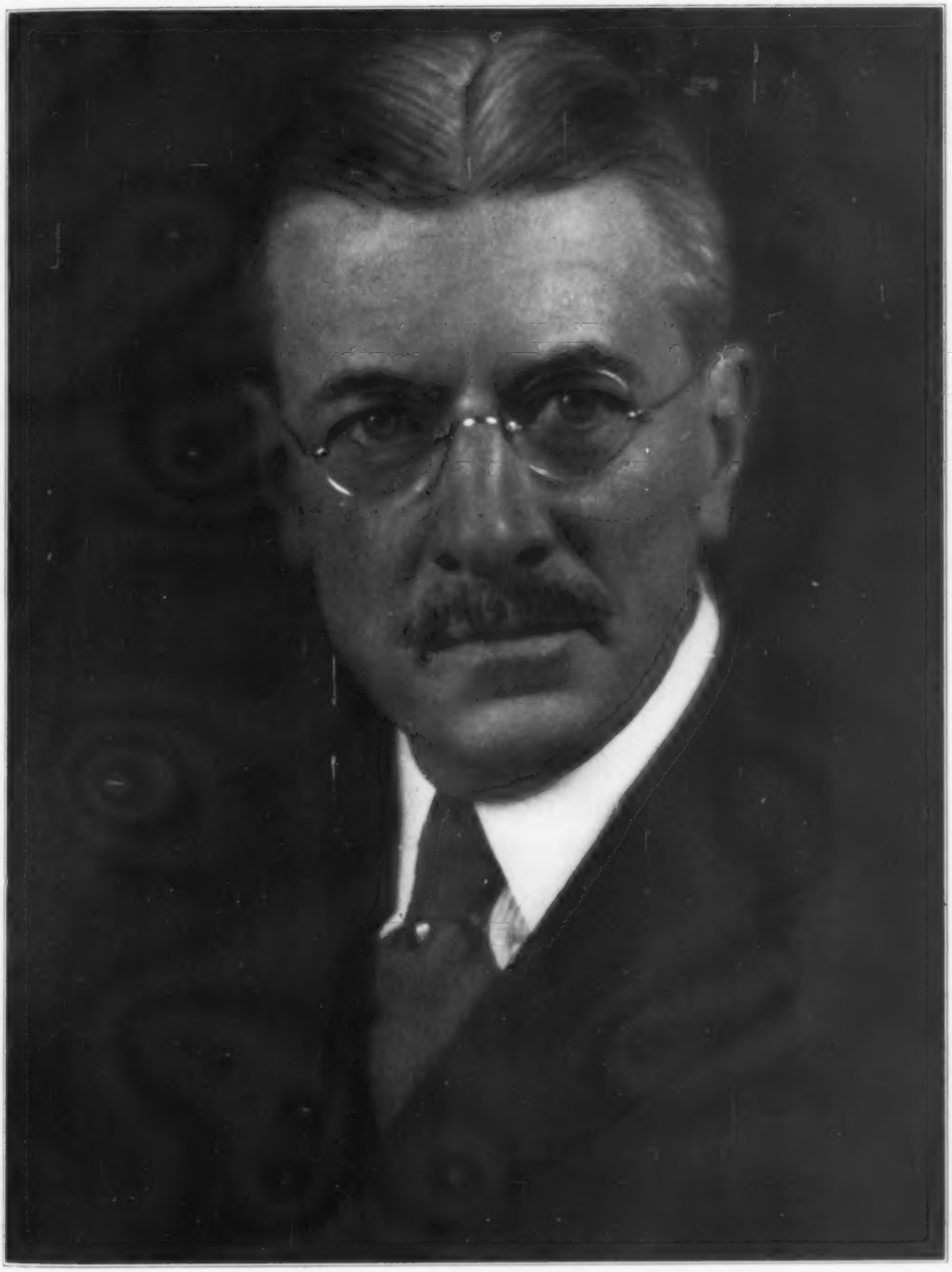
He was, above all, a gentleman in every sense of the word. In spite of poor health, he continued his work with courage as long as was possible. He was characterized by his determination to succeed in spite of his many handicaps, and by the great bravery with which he met each succeeding illness. "Life was a wonderful adventure to him."

DAVID SILVER
1873–1946

David Silver was born in Wellsville, Ohio, March 16, 1873, the son of David Silver and Nancy Elizabeth Hammond Silver. He was graduated from Exeter Academy and Harvard University. After he had received his degree of Doctor of Medicine from Harvard Medical School in 1899, he did postgraduate work in Germany and Austria until 1901. Soon after his return to this country he entered upon his practice in Pittsburgh. He actually established orthopaedic surgery in Pittsburgh, and achieved outstanding success in this field.

Dr. Silver was Professor of Orthopaedic Surgery at the University of Pittsburgh for many years, and later was Professor Emeritus. He was head of the orthopaedic department of the Allegheny General Hospital, Pittsburgh, for thirty years. From the time of its establishment in 1919 until 1944, he was in charge of the D. T. Watson Home for Crippled Children, at Leetsdale, Pennsylvania. He was consulting orthopaedic surgeon at Children's Hospital, Pittsburgh Hospital, and the Industrial Home for Crippled Children. He was Orthopaedic Consultant for the United States Army during World War I, in the Surgeon General's office.

He contributed to the literature many publications dealing with orthopaedic problems. His medical affiliations included the American Medical Association, the Medical Society of the State of Pennsylvania, the Pittsburgh Academy of Medicine, The American Board of Orthopaedic Surgery, The American



DAVID SILVER

Academy of Orthopaedic Surgeons, and the Clinical Orthopaedic Society. He was a Founder and Fellow of the American College of Surgeons. He became a member of The American Orthopaedic Association in 1906, served as President during the year 1916–17, and was always deeply interested in the work of the Association.

Dr. Silver died at Orlando, Florida, March 22, 1946. His wife, Elizabeth Roadman Silver, survives him.

News Notes

REPORT FROM THE COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY AND THE OFFICE OF ORTHOPAEDIC INFORMATION

Since the last report, made in *The Journal of Bone and Joint Surgery* (Vol. 28, pages 401–403, April 1946), the activities of this Committee and Office have continued.

As of June 1, this office has the names of 192 medical veterans who have been discharged from the Service and who are desirous of immediate training, and the names of eighty-five who are still in the Service, but expect to be discharged during 1946 and wish their training to start during the present year. This figure is to be compared to the last report of 220, an increase of fifty-seven. There are forty-eight men in the Service who have sent inquiries to this office and who desire training when they have been discharged, which will be after January 1, 1947. This office has been notified of only an occasional vacancy. One hundred and fifty-nine letters regarding vacancies have been sent to men desirous of training.

Since the last report, there have been thirty-seven additional orthopaedic services approved for training. This figure, added to the 110 previously approved, makes 147 single or combined orthopaedic services accredited for training at this time. Nearly all of the civilian hospitals, which formally applied for approval of orthopaedic training, have now been passed on by the Council on Medical Education and Hospitals of the American Medical Association and by The American Board of Orthopaedic Surgery. The number of approved residencies at the present time is approximately 453.

Since the April report, many of the Veterans Hospitals have established their Services, which are now in operation. There have also been approved Services established in six Army Hospitals, nine Naval Hospitals, and one Marine Hospital.

This office continues to have many inquiries from fully trained orthopaedic surgeons regarding locations for practice and from Diplomates of the Board looking for trained assistants. The Office of Orthopaedic Information will continue to carry on this phase of the work.

A. R. Shands, Jr., M.D., Secretary

June 1, 1946

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Spring Meeting of the British Orthopaedic Association was held at the Royal Victoria Infirmary, Newcastle-on-Tyne, on May 24 and 25, under the presidency of Mr. George Perkins, M. C.

The Robert Jones Prize for 1945 was presented to Mr. S. Pappworth, M. Ch. (Orth.), Sheffield, for his essay on "Primary Treatment of Lacerations of the Hand".

Mr. H. Jackson Burrows paid a graceful tribute to the Australian Orthopaedic Association, in whose Annual Meeting at Sydney he and his colleagues at the Royal Naval Hospital had been privileged to participate.

Mr. E. A. Nicoll reported upon 150 miners who had suffered fractures of the thoracic or lumbar spine, which he classified as (a) simple anterior wedge fracture, (b) lateral-marginal fracture (whose special features he defined), (c) fracture-dislocation, and (d) fracture of the neural arch. The results of simple wedge fractures did not depend necessarily upon the presence or absence of deformity. Hyperextension treatment would not promote repair of a concomitant injury of the intervertebral disc, and was itself often a source of chronic lumbar strain; consequently, Mr. Nicoll now preferred early exercises, with no more restraint than bed rest.

Mr. J. K. Stanger dealt with cases of fracture-dislocation of the spine, which occurred mostly in the thoracolumbar and mid-cervical regions. Paraplegia was commonest, with injuries at the narrowest parts. Recoverable cases of paraplegia could not be distinguished from those that were irrecoverable, and consequently reduction should be attempted. When open reduction was done in cases with locked facets, partial facetectomy was rarely required; and exposure might even reveal that spontaneous reduction had begun, only hyperextension being required for its completion. Although the results of open reduction in these cases with locked facets and paraplegia were exceedingly disappointing, and although closed reduction could be achieved, Mr. Stanger did not yet feel able to advocate closed reduction as the usual procedure. Fixation was by plaster jacket or, if posterior structures were fractured, by plaster bed. Redislocation, which was frequent, did not cause recurrence of cord symptoms and was often followed by bony ankylosis. The first evidence of recovery from paraplegia might appear as late as six weeks after the injury, and the extent of delay was no measure of the prognosis. Patients in various degrees of recovery after paraplegia from fracture-dislocation were shown.

Mr. W. Grant Waugh gave a restrained account of his studies of the pH of acute and chronic joint

effusions, and of his attempts to modify the pH by the injection of appropriate liquids. A clinical estimate was given of the results of treating the joints in osteo-arthritis and rheumatoid arthritis by intra-articular injections of a solution of lactic acid and procaine of approximately constant pH. The injections were followed by exercises and later by manipulations, which were facilitated by the injections and formed an integral part of the treatment. Procaine solutions were not a satisfactory substitute. Mr. Waugh asked for trial of the method by others. Some present were able to report encouraging results.

Mr. Pridie advocated excision of the calcaneus in very severe cases of comminution, and showed film strips to demonstrate the supple feet, good gait, and powerful plantar flexion which might follow this procedure, if continuity of tendo calcaneus and plantar fascia was maintained. He considered that the subcutaneous fibrofatty pad and the partially regenerated bone provided a serviceable heel. In the lively discussion which followed, the consensus was in agreement with Mr. Pridie's condemnation (following Eastwood) of immobilization of these fractures; strong in advocacy of early movement without weight-bearing; but condemnatory of so drastic an operation, and particularly of its performance through a longitudinal dorsoplantar incision.

Mr. E. W. Knowles had found that mid-tarsal dislocation might follow either a fall from a height or a torsion injury, such as that resulting from a fall with the fore part of the foot trapped. Reduction was very insecure. Consequently he advocated transfixion of the joint with a Kirschner wire, passed through the navicular and talus, and incorporated in plaster-of-Paris for four weeks.

Mr. J. B. Reid had investigated the results of McMurray's displacement osteotomy of the femur in osteo-arthritis of the hip and in ununited fractures of the femoral neck. Of thirty-six patients with osteo-arthritis, twenty-eight were completely relieved of pain. Among thirteen patients with ununited fractures, union followed in seven and one patient died.

Mr. P. H. Newman, D.S.O., M.C., discussed the clinical diagnosis of fat embolism, which had been frequent in war injuries and, if sought, would probably be found to be correspondingly frequent in civil life. Mention was made of the psychological changes, pyrexia, tachycardia, increased respiratory rate, raised blood pressure, petechiae of characteristic distribution, fundus changes, presence of fat in the last-voided urine, and the lack of information given by the sputum. The importance of efficient splinting and transport of patients with fractures was stressed. Mr. Newman had ligated the deep femoral vein in two cases, in one of which recovery occurred.

Mr. A. Graham Apley gave a preliminary demonstration of a test designed to aid discrimination between meniscal tears and sprains of the knee.

Clinical cases shown included unilateral adolescent coxa vara (slipped upper femoral epiphysis) in a father and each of his twin sons (by Mr. C. Gordon Irwin); tendon transplantations (by Mr. J. Gilmour and Mr. David Brown); melorheostosis and osteoid osteoma (by Dr. W. Mackenzie); and some results of nerve suture (by Mr. F. G. St. Clair Strange).

Mr. John Gull demonstrated an ingenious armchair for invalids, which would hoist the patient onto his feet in an upright position or, conversely, lower him gently into the sitting position, the power being provided by an electric motor.

At the business meeting, the following were elected to membership:

Full Members:

J. G. Bonnin, F.R.C.S., Newmarket
Major John Charnley, R.A.M.C.
B. Keon-Cohen, F.R.C.S., Melbourne
A. B. Pain, F.R.C.S., Leeds
I. S. Smillie, O.B.E., F.R.C.S., Edinburgh

Associate Members:

J. F. M. Frew, F.R.C.S.E., Aberdeen
George Hay, F.R.C.S.E., Brechin
L. Henry, F.R.C.S., Cheltenham
B. Isserlin, F.R.C.S.E., Bristol
Lionel E. Jones, M.S., F.R.C.S., Sutton, Coldfield
H. G. S. Korvin, F.R.C.S., Stoke-on-Trent
Walter Laurence, F.R.C.S.E., Oswestry
W. C. Lawrence, F.R.C.S.E., Coventry
H. B. Lee, F.R.C.S., London
R. N. Martin, F.R.C.S., Norwich
St. J. G. O'Connell, F.R.C.S.E., London
C. M. Squire, M.R.C.S., Chesham
Dr. Meriel Wagstaff, Bristol
M. E. Winston, F.R.C.S.E., Inverness

It was announced that the 1946 Annual Meeting would be held in London on October 18 and 19, and that the 1947 Spring Meeting would take place in Exeter.

Current Literature

CHIRURGIE DE LA MAIN: LIVRE DU CHIRURGIEN. CHIRURGIE RÉPARATRICE DES TRAUMATISMES DE LA MAIN. Marc Iselin. Paris, Masson et Cie, 1945. 145 francs.

One cannot help expressing a word of admiration for the energy and courage which impel men to stick to their appointed tasks when "the going is tough". One can visualize a few of the many difficulties that must have been overcome before this volume appeared in print, and everyone interested in the surgery of the hand will join in extending congratulations to the author on his achievement.

In a concise classification of the lesions which result from injury, Iselin divides them into four groups: those with loss of the hand or a part of it; those with digits rigid (*enraidis*) as a result of joint involvement; those with digits fixed by scar tissue (*bridés*); and those with loss of active movement, due to nerve or tendon injury (*inértes*).

After a brief discussion of the principles of splinting and of various forms of physical therapy, the author discusses, in turn, joint lesions, injuries and loss of the covering tissues, tendon injuries, and nerve injuries. In the three final chapters he considers the problems of painful stumps, of replacement of injured digits (with especial emphasis on the thumb), and of substitutes for the amputated hand.

In his discussion of tendon injuries (forty-eight pages of the total of 230), the author follows along the lines outlined in his earlier work on surgery of the hand. He gives credit to Bunnell for many of the fundamental principles described, and in the main the technical procedures described are well illustrated. One would be glad to see more illustrations of the results that have been achieved. In his discussion on re-formation of the thumb (thirty-three pages), the author includes illustrations from Sauerbruch, Lexer, and de Györ, in addition to several of his own. It is difficult, however, to convince oneself that the results obtained justify the extensive surgical procedures described.

Without agreeing with all the procedures and suggestions which Iselin recommends, one must recognize his serious and enthusiastic effort to raise the standards of surgical care for patients with hand injuries. For that effort he deserves every commendation.

A HISTORY OF MEDICINE. Douglas Guthrie, M.D., F.R.C.S. Ed., F.R.S.E. Philadelphia, J. B. Lippincott Company, 1946. $6.00.

It is difficult to comprehend the attitude of medical practitioners who are not concerned with the history of the profession which they have chosen to follow. There is, however, no doubt that this is the prevalent attitude. Possession of this volume of Guthrie's would do much to dispel this attitude, for it not only cites the development of the art of medicine as it took place in successive periods of the world's history and in the hands of different nationalities, but it brings into the picture the part played by the outstanding practitioners in those different periods in a way that makes the narrative more interesting than is often the case in medical histories. Toward the end of the volume the author deals with the rise of specialization and of preventive medicine, and finally devotes a number of pages to medical journalism and bibliography.

A feature that adds greatly to the value of the book and should encourage the reader to go further in his studies is the list of references which have furnished the material out of which this volume has been, to a considerable extent, compiled.

Everyone in practice, as well as those in the process of acquiring their medical training, should possess this book.

EL CODO SUS FRACTURAS Y LUXACIONES (The Elbow: Its Fractures and Dislocations). Antonio H.-Ros Codorníu. (Colección de monografías sobre ortopedia y traumatología, Vol. 2.) Madrid, *Cirugía del Aparato Locomotor,* 1945.

This is an exceptionally good monograph on the elbow, and would be in a leading position in any language. It is beautifully done, and the author has taken great pains to cover the subject completely.

Three chapters are given over to the embryology, anatomy, and biomechanics of the elbow. All of these subjects are discussed in great detail. The next ten chapters deal with specific types of fracture of the elbow, and they are treated according to anatomical types and regions. The author has a detailed classification of elbow-joint fractures, which is on a sound basis and easy to remember. In each type of fracture, the subject is treated under the headings of general considerations, physiopathology, pathogenesis, pathological anatomy, symptoms, diagnosis, treatment, and prognosis. Excellent illustrations, both drawings and roentgenograms, are presented. The author quotes end-result statistics, both his own and those of other authors, which greatly enhance the value of the book.

The author has the faculty of combining the qualities of a textbook with those of an advanced and interesting treatise. In general, the treatment of fractures of the elbow is along lines frequently used by American orthopaedic surgeons. Treatment is completely up-to-date. There is considerable

tendency to stress open reductions, in contrast to the extensive use of traction which was in favor some time ago. Approaches for the various open reductions are dealt with in detail and are very well done.

The author has a number of original ideas. His method of holding complete fractures of the olecranon reduced during open reduction is by use of a heavy piece of wire, bent in the form of a very long staple with short points. Roentgenograms illustrating his method show excellent reduction of the fracture and retention of the fragments. In numerous other cases staples were used, as in the fracture of the trochlea, in which a very long, narrow staple was used. Another of the author's original ideas is a somewhat complicated clamp for holding reduced badly comminuted or T fractures of the lower end of the humerus while internal fixation is being applied.

The Monteggia fracture is treated as a separate entity, a whole chapter being devoted to it. Another entire chapter is devoted to dislocations of the elbow, and a long and excellent chapter to reconstructive surgery of the elbow joint. Posttraumatic ossification, nerve lesions, and Volkmann's contracture are all treated in separate chapters.

Innumerable references to the literature are included, and many references to recent American publications were noted. A good bibliography, divided according to subjects, is placed at the end of the book. All in all, it is an excellent book and will prove of great value to its readers.

TRAITEMENT ORTHOPÉDIQUE DE LA PARALYSIE INFANTILE (Orthopaedic Treatment of Infantile Paralysis). M. Boppe. Paris, Masson et Cie, 1944. 140 francs.

From the preface to its short terminal bibliography, this small monograph impresses the reviewer by its essential sincerity and good common sense. It does not pretend to the dignity of a reference book, but it obviously represents the wide personal experience of the author in the treatment of all stages of infantile paralysis. In all its phases, poliomyelitis is the orthopaedic disease *par excellence*. With the exception of electrotherapy, all modalities of treatment—reeducation, mobilization (passive or instrumental), the making of braces, and surgical intervention—are strictly within the domain of the orthopaedic surgeon. Although there is evidence in the book that the author is well aware of what is happening throughout the medical world, no mention whatsoever is made of Sister Kenny or the treatment which she advocates.

Throughout this work, the author constantly stresses the importance of viewing the patient as a functional unit. He believes that the orthopaedic surgeon who views his patient solely from the mechanical or morphological point of view often commits the worst of therapeutic errors. It is not a question of what operation can be performed, but of what must be undertaken. Boppe states that Nature, which we imitate, often finds a solution superior to that which we possess, and there are cases in which refusal to operate is more valuable than an aggressive therapy. Conservative methods and the wearing of apparatus designed for temporary or permanent use is the keystone of therapy. Surgery is to be employed principally in the last stage of the disease. Surgical treatment has the sole objective of freeing the patient from the use of apparatus.

With this point of view, the author divides his work into two parts. The first part is concerned with such topics as the manner of examination, the prevention and treatment of poor positions, and the general treatment during the stages of recuperation and residual paralysis. A chapter is devoted to a consideration of each of the following topics: the paralytic foot, the paralytic knee, the paralytic hip, the paralytic trunk, the paralytic upper extremity, and the extensive monoplegias and paraplegias of the lower extremity. The work is sparsely illustrated with line drawings and a few roentgenograms. However, the text is so clearly thought out and so concisely expressed that the want of illustrations is not particularly felt.

While it adds nothing new, this is such an excellent clinical monograph that both the student and the teacher will find it profitable reading.

SURGICAL TREATMENT OF THE NERVOUS SYSTEM. Edited by Frederic W. Bancroft, A.B., M.D., F.A.C.S., and Cobb Pilcher, M.D., F.A.C.S., Philadelphia, J. B. Lippincott Company, 1946. $18.00.

This outstanding work, to which contributions of chapters or sections have been made by seventeen well-known American surgeons and neurosurgeons, is a companion piece to Bancroft and Murray's "Surgical Treatment of the Motor-Skeletal System". It presents detailed and comprehensive descriptions of many special technical methods, and includes a consideration of the surgery of the various disorders and lesions which comprise the field of neurosurgery.

A large proportion of the book is devoted to cranial and intracranial surgery; other sections deal with surgery of the spinal cord, surgical lesions of the peripheral nerves, surgery of the sympathetic nervous system, and the relation of chemotherapeutic agents to neurosurgery. It has excellent illustrations, including a few color plates.

This is a carefully and critically prepared work, dealing with a complex and specialized field of surgery, but it will have great value for the general surgeon as well as for the specialist in the field of neurosurgery. It cannot be recommended too highly.

PENICILLIN THERAPY AND CONTROL IN 21 ARMY GROUP. Published under the direction of the Director of Medical Services, 21 Army Group, with Introduction by the Consulting Surgeon. Printing and Stationery Service, British Army of the Rhine, May 1945.

This book records observations and investigations carried out in British and Canadian hospitals of 21 Army Group in the European Theater throughout the Continental Offensive. It would appear that this was the first British Army group to receive unlimited supplies of penicillin,—sufficient for parenteral therapy. The various reports furnish an interesting sequel to the observations of Florey and Cairns upon the local use of penicillin.

Acknowledging the essentiality of primary surgery, the authors accredit penicillin as a major factor in the diminution of wound sepsis. Sulfonamides were found to be unnecessary, and an undesirable supplement to parenteral penicillin therapy in wound management. Penicillin was preferred by many surgeons for abdominal wounds.

The advantages of the parenteral route, even at the most forward surgical levels, were established. Supplemental local chemotherapy was widely used, especially for wounds of the knee joint and chest. A powder of calcium penicillin and plasma failed to prove effective in the local treatment of burns.

Penicillin is considered to have contributed to the expanded program of delayed primary suture. "Since the advent of penicillin the base hospital surgeon has become an animated sewing machine". The various contributors emphasize the technical details of wound management which are essential to success.

In summary, this volume records a series of "random samples", sufficient to grant significance to the general conclusion that parenteral penicillin therapy has contributed to a conspicuous absence of wound sepsis. The consideration of technical details of wound management further identifies these reports as important source material for the medical historian of World War II.

ACCIDENTES VASCULARES DE LOS MIEMBROS (Vascular Accidents of the Limbs). F. Martorell. Barcelona, Salvat Editores, S. A., 1945.

Martorell, as chief of the section in vascular surgery at the Polyclinic Institute of Barcelona, has had a wide experience in disturbances of the circulation. Many of these disturbances appear suddenly and lead to serious complications. For these, he considers the name vascular accidents to be most appropriate. The physiopathological mechanisms, the symptoms, and the treatment of these accidents are discussed. Arterial disturbances are discussed in Part I and venous disturbances in Part II.

The book has many excellent sketches, which show the circulatory disturbance at a glance. In addition, case histories accompany the sections on treatment. This is a very effective method of presenting the material. The book is written clearly. In addition to the sketches, there are many good pictures. An extensive bibliography is added.

An English edition of this work would be of great help, particularly to orthopaedic surgeons who see many disabilities associated with circulatory disturbances of the limbs.

ANATOMICAL ATLAS OF ORTHOPAEDIC OPERATIONS. L. S. Michaelis, M.D. London, William Heinemann Ltd., 1946. 25 shillings.

This small book is based, quite properly, upon methods of approach and exposure. It is quite unambitious: detail is scanty; and alternative incisions, with their respective purposes and merits, receive only brief mention. It will be useful in helping the beginner to orientate himself, especially as there are references to original descriptions of operations; otherwise, it is in no sense a book of reference or an adequate guide to the aspiring orthopaedic surgeon. In short, it may be used as an early stepping stone to more thorough information.

TRAITEMENT CHIRURGICAL DE L'ARTHRITE SÈCHE DE LA HANCHE. SUIVI DE TRAVAUX DE LA CLINIQUE ORTHOPÉDIQUE DE LA FACULTÉ DE LYON (Surgical Treatment of Osteo-Arthritis of the Hip). L. Tavernier and Ch. Godinot. Paris, Masson et Cie, 1945. 150 francs.

This volume of over 350 pages is divided into three parts. The largest amount of space is devoted to the treatment of chronic osteo-arthritis of the hip, especially by the method of enervation. The second part takes up the surgical treatment of other joints. The third part is largely a compilation of abstracts of articles on the treatment of many other conditions,—such as scoliosis, protrusion of the disc, and osteosarcomata.

The first part presents an interesting review of the symptomatology and treatment of chronic osteo-arthritis of the hip. Treatment by means of subtrochanteric osteotomy, arthrodesis, and arthroplasty are reviewed hastily. In the unilateral cases, arthrodesis appears to be the operation of choice. The authors believe that it is a heroic method, but the most trustworthy in the treatment of arthritis of the hip. However, the possibility of bilateral involvement necessitates arthroplasty on at least one side. Of a series of seventeen cases submitted to arthroplasty, satisfactory results, both as regards relief of pain and range of motion, were obtained in twelve.

Subtrochanteric osteotomy should be reserved mainly for the correction of an awkward position.

Its use as a primary treatment in arthritis is not entirely satisfactory, because it leads to limitation of motion. The shelf operation is recommended only when the osteo-arthritis is secondary to a congenital dislocation of the hip. The authors stress the importance of creating the shelf at the level of the head, without traction. Drilling of the femur is useless, as it gives only temporary relief.

As a simple method of relieving pain, especially in those cases in which a more radical operation is contra-indicated, the authors recommend enervation of the hip.

The sensory supply of the hip joint is derived through the posterior division of the obturator nerve, the femoral nerve, and the sciatic nerve. The anatomy of the obturator nerve and of the articular branch of the sciatic nerve is discussed, and the technique of section of these nerves is described.

Of fifty-seven cases in which the obturator alone was resected, immediate relief of pain was obtained in forty-five, or 82 per cent. With the lapse of time, however, recurrences were observed in a number of these cases. Six patients could not be followed, but, of the remaining fifty-one, fourteen were completely successful and five showed marked improvement. Thirty-one had return of pain, and of those who submitted to a secondary resection of the sciatic nerve, seventeen were immediately relieved of pain.

The authors believe that this is the operation of choice in all cases in which the affection is bilateral or in which arthrodesis is contra-indicated. It is a simple procedure, which does not produce shock and does not reduce the range of motion in the hip.

The second part of the book is devoted to an application of the principle of enervation to other joints, such as the shoulder, the knee, the ankle, the wrist, and the toe. The specific nerve to be cut and the technique of exposure are described in each instance. The method is interesting and should have a definite field of usefulness where more specific therapy cannot be applied.

THE TRAUMATIC DEFORMITIES AND DISABILITIES OF THE UPPER EXTREMITY. Arthur Steindler, M.D., F.A.C.S., in collaboration with John L. Marxer, M.D. Springfield, Illinois, Charles C. Thomas, 1946. $10.00

In these days when so much thought is being given to reconstructive surgery, this excellent book on traumatic deformities of the upper extremity will fill a real need.

The different disabilities of the upper extremity are grouped according to the type, nature, and extent of functional impairment, rather than by anatomical classification. Certain functional disabilities may result from different injuries. The plan of treatment may be similar, while the etiology of the traumata varied greatly. Moreover, accidents which appear very similar—such as fractures of a definite bone at the identical site—may result in deformities which are markedly different. Therefore, the emphasis has been placed on a functional classification of the conditions to be treated. It is recognized, however, that, from these unfortunate results, much can be learned about the value of the methods of the primary treatment.

Part A is devoted to general considerations of traumatic disabilities of the upper extremity. In Part B are discussed the traumatic disabilities of the special parts,—as Shoulder Girdle and Arm, Elbow Joint, Forearm and Wrist, and Hand and Fingers. Under each of these large sections are considered the various types of disability and deformity; for each of these types is presented the pathogenesis, symptoms, and methods of treatment. Then follow illustrative case reports of each condition described, with references to others in the literature. About 260 of these case reports are presented, drawn not only from the authors' wide experience, but also from current medical literature.

The book represents a vast amount of study and careful, analytical thought. The publishers have presented this material in most attractive form. Surgeons for years to come, who will find this book of practical help, will be indebted to Dr. Steindler and his associates for this painstaking work.

PATHOLOGY IN SURGERY. N. Chandler Foot, M.D. Philadelphia, J. B. Lippincott Company, 1945. $10.00.

Dr. Foot, who is Professor of Surgical Pathology at Cornell University Medical College, has made a careful selection of pathological conditions, which has resulted in a book that covers the subject adequately. His discussions are clear and are sprinkled with his characteristic whimsies. The volume is liberally illustrated, but the photomicrographs have not all been reproduced clearly; this is particularly true in the section on skin. The author's colored drawings might well have been omitted, for they undoubtedly added considerably to the cost of publication, without a comparable contribution to usefulness. The general format of the book is quite satisfactory.

The book opens with a chapter on technical and administrative suggestions for the surgical pathologist, followed by discussion of the basic principles of inflammation and repair and the general pathology of tumors. The remainder of the volume covers in a unique way the pertinent pathology of the tissues and organs, with emphasis, of course, upon those conditions with which the surgeon is especially concerned, including the nervous system and the skin.

This book is a convenient reference for the surgeon and for the hospital pathologist. It should prove valuable to both of these groups.

THE MANAGEMENT OF FRACTURES, DISLOCATIONS, AND SPRAINS. John Albert Key, B.S., M.D., and H. Earle Conwell, M.D., F.A.C.S. Ed. 4. St. Louis, The C. V. Mosby Company, 1946. $12.50.

This excellent work by Key and Conwell, now in its fourth edition, is well on the way toward becoming a classic in its field. As compared with previous editions, the principal changes in the present volume occur in the sections on the hip, on injuries to the spine, and on the treatment of compound fractures and war wounds. A discussion of chemotherapy has been added as it affects various phases of treatment. Some of the old illustrations have been replaced, and new ones have been added. Methods of treatment which are considered obsolete have been omitted, and experience gained during the War has been included.

This book has earned and maintains an established position in a field in which good texts abound. The original statement of the authors — that it was "written for the student, the general practitioner, and the surgeon" — applies equally to the most recent edition.

MOTOR DISORDERS IN NERVOUS DISEASES. Ernst Herz, M.D., and Tracy J. Putnam, M.D. Morningside Heights, New York, King's Crown Press, 1946. $3.00.

Because orthopaedic surgeons are concerned primarily with disorders of the musculoskeletal system, this new textbook on motor disorders in nervous diseases will be of interest to them. According to the preface, the authors intended originally to make a group of films, suitable for teaching, on motor disorders caused by various nerve diseases. It became apparent that a syllabus to accompany the films would be of value, and eventually this syllabus was expanded and illustrative material was included by reproducing individual frames from the motion pictures.

The chapters on Involuntary Movements in Nervous Diseases, Disorders of Gait, Disorders of Coordination, Muscle Status, Reflexes, and Skilled Acts will be helpful to orthopaedic surgeons.

It is somewhat disappointing that the authors could not have analyzed, in more detail, disorders of gait caused by infantile paralysis and cerebral spastic paralysis. Due to the fact that the illustrations are taken from sixteen-millimeter motion-picture film, they are not of particularly good quality. However, they do present satisfactorily the various motor disorders as they occur clinically.

This volume will undoubtedly find its greatest usefulness as an introductory text for students of neurology and as a "refresher" for neurologists, neurosurgeons, and orthopaedic surgeons.

HOSPITAL CARE OF THE SURGICAL PATIENT. A SURGEON'S HANDBOOK. George Crile, Jr., M.D., and Franklin L. Shively, Jr., M.D. Ed. 2. Springfield, Illinois, Charles C. Thomas, 1946. $3.50.

The second edition of this timely handbook is more than a hundred pages longer than its predecessor. Part of this increase is due to the inclusion of an Appendix on the treatment of wounds, written by one of the authors and reprinted from Lewis' "Practice of Surgery". The material in the Appendix is in keeping with the rest of the volume, which is intended primarily for the use of surgical interns and house officers.

The authors deal with the physiological principles involved in the treatment of surgical patients, the treatment of the more common surgical complaints, and preoperative and postoperative care. There is an excellent and detailed section on the technique of common hospital procedures. A short section on the relation of the house officer to the patient and another in which dosages and diets are discussed close the main portion of the volume.

In general, the handbook serves its purpose well, and should be extremely useful as a guide to young surgeons and busy interns.

PRECPERATIVE AND POSTOPERATIVE TREATMENT. Edited by Lieutenant Colonel Robert L. Mason, M.C., A.U.S., and Harold A. Zintel, M.D. Ed. 2. Philadelphia, W. B. Saunders Company, 1946. $7.00.

The contents of this book of 584 pages are divided into two parts. Part I covers general preoperative and postoperative problems; Part II consists of similar discussions from a regional standpoint. Many of the chapters have been written by physicians who are recognized specialists in their fields. The subject matter represents, for the most part, the accepted teaching in Boston on each specific problem. The articles are amply and well illustrated.

Recent advances in surgical care have been rapid, due largely to utilization of applied physiology, biochemistry, bacteriology, and pharmacology. Accordingly, any authoritative consideration of surgical care must be recent. This necessitated rewriting practically every chapter in the first edition. This has been done with such meticulous care that the second edition will prove of great value to any physician who has to care for a surgical patient. Not only will he obtain invaluable aid on general problems, but he will also find helpful information concerning the specific region in which he may be interested.

Although, for the most part, the contents of this book present the teachings which Boston accepts in regard to surgical care, a notable exception is the chapter on burns. Extraordinary achievements which have resulted from studies of burns during the War are not reflected in this section. The statements on skin-grafting are particularly inadequate, because the Padgett dermatome and the very important grafts taken with it are not mentioned.

The book is concluded with a very useful Appendix, covering laboratory findings in the blood and urine in health and disease.